APPENDIX A

ADVANCE

Advanced Driver and Vehicle
Advisory Navigation Concept

Traffic Related Functions
Evaluation Report (1 of 7)
Documents # 8460.00

CONTAINS:

Prepared by
University of Illinois-Chicago
Urban Transportation Center

DISCLAIMER

ADVANCE Evaluation

Base Data and Static Profile

Ashish Sen, Helen Condie, Aaron Sheffey, Xin Tian
and Xiaoqun Zhu

URBAN TRANSPORTATION CENTER
University of Illinois at Chicago
1033 West Van Buren Street
Suite 700 South
Chicago, Illinois 60607

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Executive Summary

For every link static profiles are default travel times used by the probe vehicle's MNA when dynamic travel-time estimates are not available. Dynamic estimates may not be available for two reasons: equipment failure, which is rather rare; and when dynamic estimates do not differ adequately from the static profiles and are therefore not broadcast. The latter situation is a property of the ADVANCE architecture and is based on the fact that dynamic estimates, based on very few observations, have large variances and unless they differ substantially from the static estimate, the static estimates are more reliable.

Since, when the demonstration started no probe data had been gathered, initial static profiles were constructed synthetically using an algorithm called the NFM algorithm. As data became available, the profiles were updated.

The purpose of the task reported on here is to evaluate the quality of the static profiles: both the initial profiles and their updated versions. For this purpose data were collected by probe vehicles for a 13-link network in the ADVANCE study area over a 12-week period. Static-Profile updating was performed every three weeks or so.

While the initial profiles did not reflect link travel times exceptionally accurately, this is understandable given that they were not based on any data that reflected link-specific conditions, either from probes or detectors. However, the updates substantially improved the quality of the estimates.

During the design stage of ADVANCE, each weekday was to be subdivided into 48 intervals for each of which the static profile would provide a single travel-time estimate for each ADVANCE link. However, during targeted deployment the number of intervals was reduced to 5 because not enough data would be gathered on most ADVANCE links to construct reliable updates. Since enough data were available for the links under study, both the 5-interval profiles and more detailed lo-interval profiles for 6-hour periods were examined. The profiles were evaluated in terms of their ability to match mean travel times and in terms of their efficacy as forecasts.

Overall, it was found that, especially after a few updates, static profiles were exceptionally accurate. The algorithms performed robustly against idiosyncratic probe-reported observations. Profiles based on probes only were found to be more accurate than those based on both probes and detectors.

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1 Introduction

1.1 Background

In the ADVANCE system, the Mobile Navigation Assistant (MNA) in equipped vehicles computes desirable routes based on predicted travel times. Some of these estimated travel times are obtained via radio from a central computer, called the Traffic Information Center (TIC). The MNA receives broadcasts only when the car ignition is turned on. Few drivers would be willing to wait very long to get route guidance after they have entered the car; on the other hand, there are over 10,000 links in the system and the radio frequencies (RF) available have modest capacities. Thus, it is impossible to broadcast information on all links and have it available for the initial guidance given to the driver. Consequently, default travel time predictions need to be available to the MNA. These defaults would be overwritten by real-time estimates of travel time (available via RF communication) when these real-time or dynamic estimates differ significantly from the default estimates. Moreover, the default estimates would also be available in case transmissions are interrupted.

These default travel times, based on historical and other information, reside on a compact disk in the MNA and are called Static Profiles (SP). They are also contained within a corpus termed the Static Profile Database (SPD). Initial profiles were constructed using the Network Flow Model (NFM) and are contained in the Base Data (BD) component of Traffic Related Functions (TRF). After enough data have been collected from probes, the NFM estimates (BD) are revised using a procedure called Static Profile Updating (SPU). As more data are collected further revisions occur using a slightly different version of the SPU procedure.

The Base Data and Static Profile process may be summarized as:

1. initial travel time profiles constructed using the Network Flow Model, stored as Base Data,

2. travel time data collected from probes,

3. Network Flow Model estimates of travel times revised using a procedure called Static Profile Updating (SPU), the products of these updates being called Static Profiles (SP); and,

4. further data collection and revisions of SP, using the Static Profile Updating procedure.

During the summer of 1995 an average of twelve vehicles were driven four days a week over an eleven-week period. During this time almost 60,000 miles were driven to produce over 50,000 link reports within a confined study area. While these reports have been and will be used for several purposes, they also provide the travel-time data required to perform static profile updates.

The purpose of the BD/SP task is to assess the quality of the Base Data estimated by the Network Flow Model (NFM) and the quality of the static profiles (SP) estimated by the SP update algorithm. The validation of the NFM will be based on data from a representative sample of links by comparing probe data to outputs from the NFM. Similarly, the validation of the static profiles will be based on a representative sample of links by comparing probe data to static profile data.

The aim of the base data and static profile evaluation task is therefore to assess the quality of the initial NFM estimates and the results of several updates of these estimates. The procedures followed for both data collection and analysis are taken directly from the Evaluation Test Plan (ETP) for BD/SP. For convenience we call the NFM estimates BD estimates and reserve the name SP for results of updates. The ETP states that this task will test two hypotheses. The first hypothesis is that the NFM consistently and accurately estimates travel times. The second hypothesis is that the SP consistently and accurately estimates travel times.

Since the whole purpose of the BD and SP estimates is to reflect average travel times, most comparisons made below are with such averages computed from travel times reported by probes.

We used data gathered during the summer of 1995, from lpm to shortly after 7pm, Monday through Thursday for a 12-week period. Our overall assessment of the SPU algorithm as applied to this data is that in the version of TRF that has been implemented, the static profile estimates on nearly all links are very accurate once a reasonable amount of probe data becomes available. This is reflected in the increasing accuracy of SP runs as more probe data becomes available. We can make the conjecture that the SPU algorithm would work equally well with data from all day types and time periods.

Although we have noted possibilities for improvement, these are confined to subcomponents. While these deficiencies should be addressed in future implementations, the overall performance of the system as implemented is more than acceptable.

1.2 Data-Collection Schedule

Data were collected on several study routes Monday through Thursday from June 5th to August 10th. At the beginning of each day of data collection, a twelve-noon briefing was held at the ADVANCE office in Schaumburg. At this time the drivers were assigned vehicles and they left the office at approximately 12:30pm. Each driver used a designated route to drive to the study area. There were several different routes; this report is not concerned with the routes to and from the study area. Data were collected by probe vehicles driven in the study area between lpm and 7pm (Table l), with breaks as described below.

On each day of data collection a field manager was present at the staging area. The field manager ensured that vehicles were driving the study route at satisfactory headways and instructed drivers when to take breaks. An effort was made to release the probe vehicles at random intervals but variations in probe travel times caused some deviation

Table 1: Probe Reports for each Hour of Data Collection

Hour Beginning	No of Reports	Percent of Total
1pm	8464	16.7
2pm	7980	15.8
3pm	5187	10.2
4pm	8488	16.8
5pm	8433	16.7
6pm	7871	15.5
7pm	4197	8.3
Total	50620	100.0

from the schemes developed to achieve random release. The field manager also assisted with MNA failures and other problems.

The drivers were given a ten-minute break at approximately 2:00pm and another one from approximately 6:00pm to 6:10pm. Each driver took his or her break at a slightly different time, since each was dispatched by the field manager to the break area as they arrived at the staging area. During breaks each probe vehicle was inactive for more than ten minutes as time was lost off-route and also because the vehicle and MNA needed warm-up time. A longer break occurred from 3:30pm to 4:00pm. After this break, during the two-hour peak period from 4:00pm to 6:00pm, the drivers operated their vehicles without scheduled breaks.

1.3 Study Area and Routes

The entire routes driven on Dundee Road and adjacent arterials were within the municipality of Wheeling, Illinois (north suburban Chicago). Dundee Road was selected because it carries a high volume of traffic and because each signalized intersection is demand actuated by loop detectors (including turning lanes) and there are volume and occupancy detectors in several locations. Although Dundee Road extends for several miles within the ADVANCE study area the number of potential places along Dundee Road where the necessary field tests could be performed was very limited. The data-collection route required a convenient location where vehicles could turn around safely and avoid being off the study route for a long period of time. For a number of the evaluation tasks (although not BD/SP, the subject of this report) the route also needed a mix of link and intersection characteristics.

Two route configurations were used for the field data collection. The first route (Figure 1) is the long route and was used for the majority of TRF evaluations, including the subject of this report. The long route consists of twelve links. The section of the route on Schoenbeck Road and Palm Drive (near the west end) was used as a staging and

turnaround area and since it was too short to complete a recognized link, data were not collected for this section of the route. The route was selected to be completed during a fifteen-minute period to achieve the density of coverage desired for most tests. During the off-peak period the majority of the drivers completed this twelve-link route in ten to fourteen minutes.
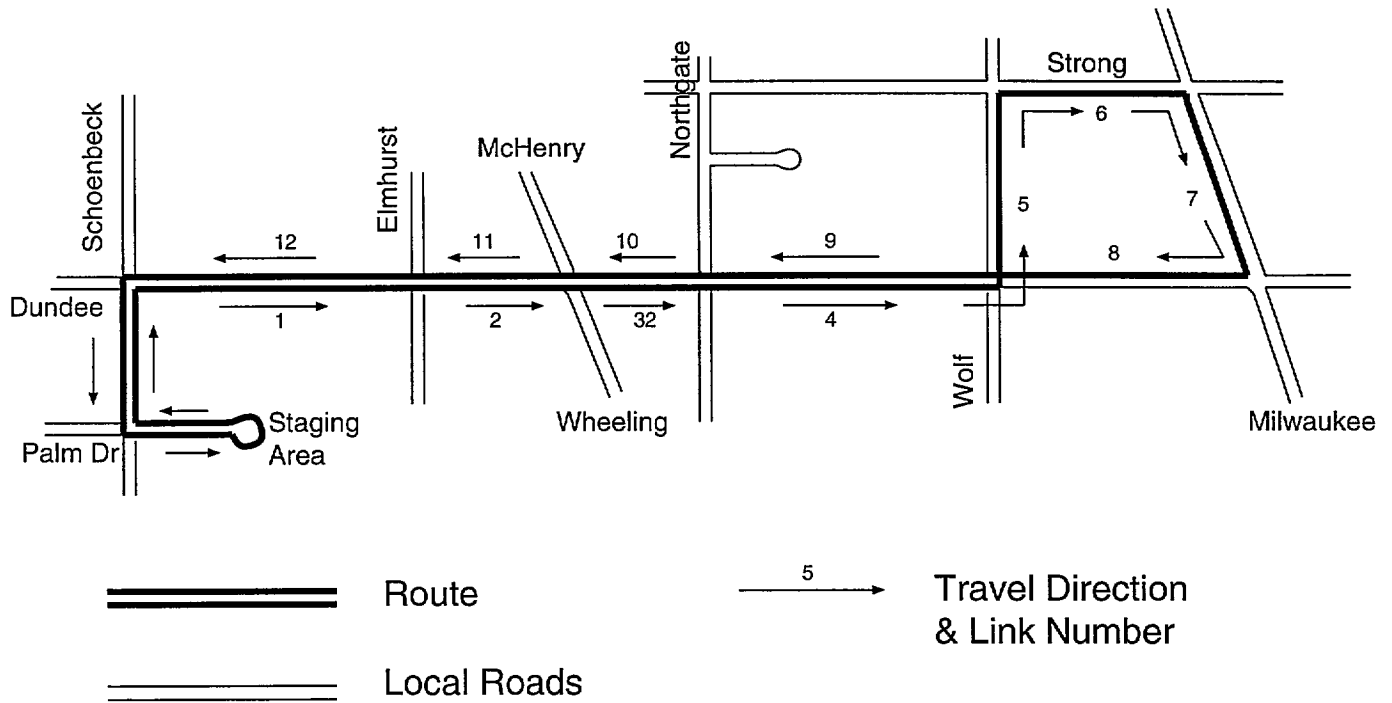
Figure 1: Probe Data Collection: Long Route

During the peak period this route proved to be too long to complete in fifteen minutes and on certain days a shorter alternative was used. This route is shown in Figure 2. Even the short route could not always be completed in fifteen minutes but this happened infrequently.

Using two different data collection routes resulted in variation in the numbers of probe reports from each link (i.e., the links solely on the long route are traversed less frequently). For the evaluation of static profiles, variation in the number of probe reports from each link is of value as it allows the exercise of the SP procedure for different frequencies of probe deployment.

Links 4 through 9 are on the long route but do not have the same number of link reports for two reasons (Table 2). First, many of the breaks were taken on this portion of the route. The most common break location was on Link 8 and there are correspondingly fewer reports on this link (the vehicles need to travel the entire link without stopping to create a report). Second, there may have been MNA failures and other reasons for turning off the link and stopping.

During the last three weeks of data collection in the Dundee Road study area the
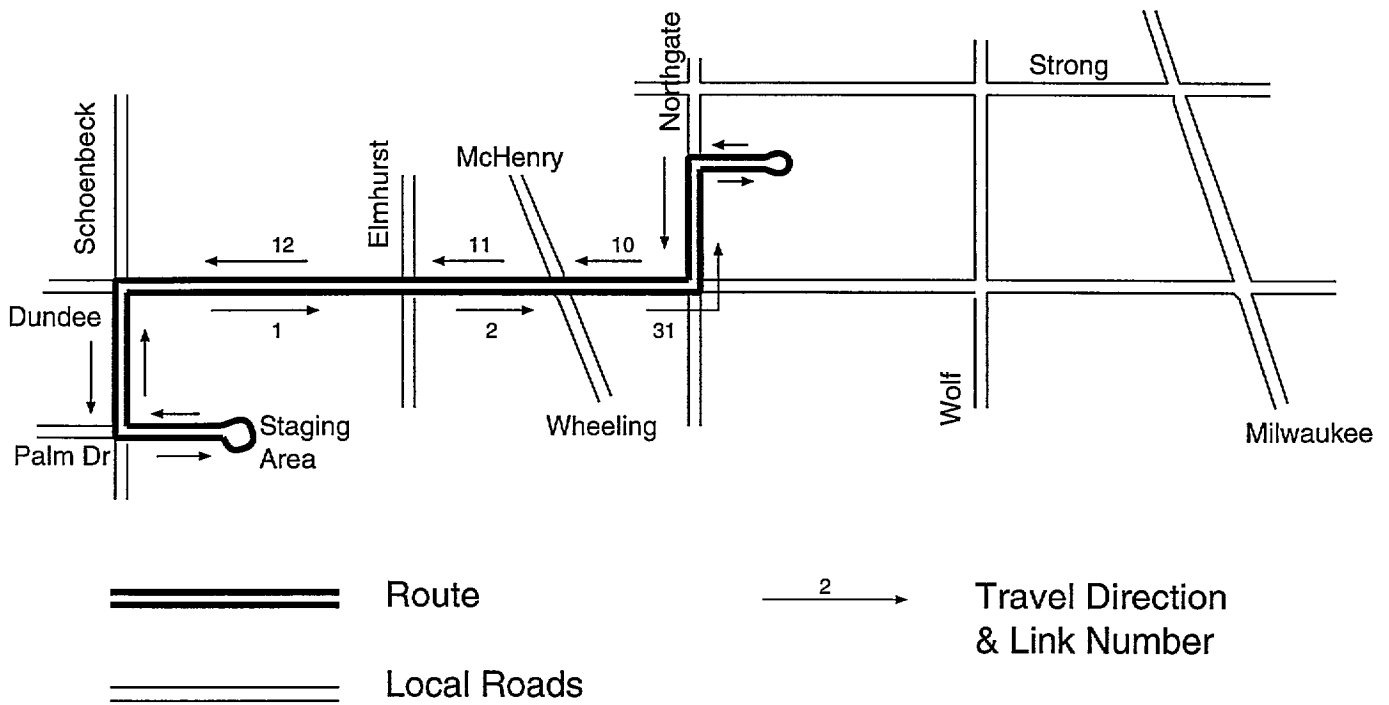
Figure 2: Probe Data Collection: Short Route

Table 2: MNA Reports by Link

Link	Frequency	Percent	Link	Frequency	Percent
1	5481	9.7	7	2323	4.1
2	6298	11.1	8	2172	3.8
3*	5886	10.4 *	9	2462	4.3
4	2313	4.1	10	6066	10.7
5	2294	4.1	11	7826	13.8
6	2293	4.0	12	5206	9.2
31*	3555	6.3 *			
32*	2331	4.1 *			
			Total	50,620	100.0

* Link 3 consists of two links, 31 and 32. Link 31 is on the short route and includes a left turn at the end of the link. Link 32 is on the long route and has a through movement at the end of the link (no turn)

vehicles were being used to evaluate turning movement travel time predictions. In this case each driver was given a set of randomly drawn routes, to be driven in sequence, which covered the links shown on Figure 3. This consisted of fourteen uni-directional links. On Link H/h the drivers were permitted to stop and study the rest of the routes they had been assigned to drive. Data collection on the turning relationships route generally yielded more than 1500 usable MNA reports per day. Over half of these reports are on Dundee Road (links A, a, B, b, E and e) and are used in deriving static profiles. The Dundee Road links are identified on Figure 3. Several of the links on the long route are traversed infrequently during this period. Again, the resultant variation in probe density on the study links is welcome for the purpose of this evaluation.
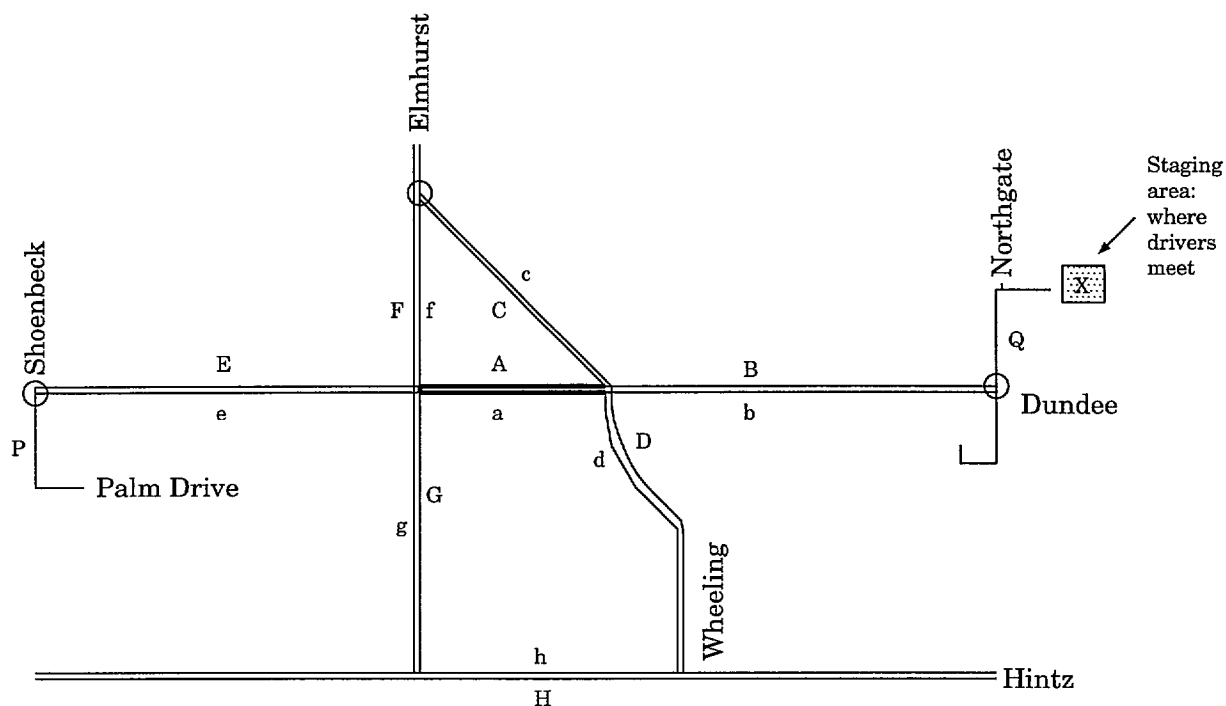
Dundee Road Links:

Link EP = Link 12	Link AE = Link 11	Link BA = Link 10
Link ea = Link 1	Link ab = Link 2	Link bQ = Link 31

Figure 3: Probe Data Collection: Turning Relationships Links

2 TRF Components Examined in this Report

In this section we outline the TRF components that are evaluated in this report. This presentation is made in order to make the report more self-contained. For details of the procedures, we refer the reader to Berka et al., 1994 and ADVANCE Working Paper No. 41 for the BD procedure and to ADVANCE Working Paper No. 49 for SPU.

2.1 The BD Procedure

Since before probe deployment occurred travel-time estimates could not be obtained from probe data, initial estimates of travel times needed to be synthesized by means of a model which used only readily available information. BD travel time estimates were therefore generated by means of a model called the Network Flow Model (NFM). Models of the NFM type are network equilibrium models and are based on the principle that every traveler minimizes his/her travel time (or some more general travel cost, a major component of which would be travel time). The total number of vehicles (OD volumes) between every origin and every destination, and a set of cost functions which describes the relation between volumes and travel times on every link are entered into the model. In this case, the NFM used cost functions which were realistic traffic engineering functions to create the BD estimates. The Chicago Area Transportation Study (CATS) provided 1990 OD volume estimates.

In the NFM used to construct the BD estimates, each weekday was divided into 5 intervals: 0000 - 0600; 0600 - 0900; 0900 - 1600; 1600 - 1800; and, 1800 - 2400. However, the CATS data provided a total demand volume for the whole day. To overcome this problem, the CATS 24-hour demand volumes were factored into volumes for specific time intervals (see ADVANCE Working Paper No. 43).

Only two of the BD intervals substantially intersect the time period over which data were collected (lpm - 7pm) and our evaluation is based on these. That is, our evaluation of BD is for the period l-4pm (the off-peak period), and for 4-6pm (the peak period).

2.2 SP Updating

When probe data became available, SPU algorithms updated BD estimates. The basic method of updating is a straightforward Bayes' procedure described in ADVANCE Working Paper No. 49. However, some additional safe-guards have also been designed. The aim of one of these was to detect major shifts in average travel times for two consecutive updating intervals, to warn the operator of this and to take other appropriate actions. This particular safe-guard was not implemented for the targeted deployment.

As designed, each weekday was to consist of 2 day types (Monday to Thursday AM and Monday to Thursday PM). Each day type would have had 24 SP intervals. When the decision was made to move from full deployment (of many thousands of probe vehicles in a large study area) to targeted deployment we moved to the 5 BD intervals. This was because, for the entire study area of full deployment, not enough data would be gathered by a small number of probe vehicles. However the targeted deployment of a small number of vehicles on a small number of links (on the study route) simulated the probe coverage of full deployment in terms of the number and frequency of probe reports per link. We are therefore in a position where we could evaluate the SP/BD procedure both *as designed* (for full deployment) and as *implemented*.

No decision had been taken as to how frequently SP updating was to occur under

full deployment (full deployment is described in the following section). However, there seemed to be a general assumption that updating was to be carried out every 2 to 3 months. Since the data gathering for the TRF evaluation was for a twelve-week period and we wished to carry out several updates, for the purpose of this evaluation we used much shorter updating time periods as indicated below.

Static profile updates were designed to be step functions; that is, the day was assumed to be divided into several intervals over each of which the SP would have a single value. We shall call these intervals, which could be several minutes (or several hours) long, **SP** intervals to distinguish them from the *updating intervals* (which would be several days or weeks long) just mentioned.

2.2.1 SPU: 2-Interval

We constructed SPU estimates for two of the 5 BD intervals (l-4pm and 4-6pm) that substantially overlapped our data gathering period. We compared these estimates to mean travel times. We call this evaluation the evaluation of SP as *implemented,* or the evaluation of the 2-interval SPU. The results of the SP updating procedure using the 2-interval schedule are presented in Section 5.1 of this report.

2.2.2 SPU: l0-Interval

We also constructed a larger number of SP intervals and evaluated SPU estimates for these. We call this an evaluation of SPU as *designed* or the evaluation of the *10-interval SPU.*

The intervals had not been defined in the SP design, the idea being that the most suitable intervals would only become apparent after some link travel time data were available. Therefore, we needed to obtain suitable intervals. The intervals that were used in the evaluation were constructed using an ANOVA-based procedure. We are indebted to Todd Graves of the National Institute of Statistical Sciences for his help in constructing suitable intervals. These SP intervals were those over which travel times on links under study were relatively constant.

The number of intervals for the SPU *us designed* evaluation was not predetermined; the statistical method used by Todd Graves identified the optimum number of intervals. Ten satisfactory intervals emerged from this procedure.

As designed there were to be 24 intervals per day type; Monday - Thursday AM and Monday - Thursday PM are two of the day types. Therefore, for our 6-hour data collection period 10 intervals looks about right. Note that we are working with short updating time periods, so that data shortage (i.e., a very small number of probe reports during the time period for the interval) is a possibility. See, for example, Tables 12 to 14. When conducting the evaluation for 10 intervals, the first update was for only 2 intervals. During the second update the number of intervals was expanded to 10. Table 3 gives the lo-interval schedule. The results of the SP updating procedure using the lo-interval

Table 3: lo-Interval Schedule (Graves)

Interval Number	Time Period	Interval Number	Time Period
1	1:00-2:30 pm	6	5:10-5:30 pm
2	2:30-3:10 pm	7	5:30-5:40 pm
3	3:10-4:00 pm	8	5:40-6:00 pm
4	4:00-4:40 pm	9	6:00-6:45 pm
5	4:40-5:10 pm	10	6:45-7:00 pm

schedule are presented in Section 5.2 of this report.

3 Data Collection and Analysis

3.1 Data Collection

In the initial design of the ADVANCE project, several thousand cars were to be deployed over 10,000 links. These large volumes were proposed in order to provide enough data to perform various TRF tasks. Instead of this large design, a *targeted deployment* using fewer cars per day over a smaller number of links was implemented. In the data collection exercise for TRF evaluations between 8 and 15 cars per day were driven over a small number of links in order to simulate, on these links, probe frequencies that would have occurred under full probe deployment.

The data used to perform SP updates were gathered over the period June 6-August 4, 1995. Data collection was divided into three collection periods for SPU purposes: June 6-June 18, June 19-July 9, and July 10-August 4. Updates were made corresponding to the last day of each collection period (i.e., June 18, July 9 and August 4).

All analyses were performed off-line after data collection was complete. Table 4 shows the periods over which data were gathered for each updating exercise. SPUx refers to specific runs of the SPU procedure, and the results of these updates are referred to as SPx or Static Profile x.

Static Profile Updates 2 and 4 are both derived using probe data collected during the time period June 19-July 09; Static Profile Updates 3 and 5 are both derived using probe data collected during the time period July 10-August 04. Static Profile Updates 1, 2 and 3 use a 2-interval schedule; Static Profile Updates 4 and 5 use the lo-interval schedule.

3.2 Sample Size

The numbers of probe reports received from each link for each interval in the 2-interval schedule are given in Tables 5 and 6. The tables also show the sample means, sample

Table 4: Static Profile Updates: Time Periods

Dates	2-Interval	lo-interval
June 6-June 18	SPU 1	
June 19-July 9	SPU 2	SPU 4
July l0-August 4	SPU 3	SPU 5

standard deviations (S.D) and sample standard errors (S.E.). It is very important to note that these quantities were computed formally using formulae contained in the statistical package SAS. These formulae are derived assuming observations are uncorrelated. Since a car following another car would have link travel times very similar to the car in front, and also because two cars arriving at an intersection at the same time after a signal has turned red would have similar travel times, even if they arrived in different cycles, probe travel times are not uncorrelated. Therefore, while the formula for the sample mean is not affected by this correlation between travel times and the standard deviation is only marginally affected, the expression for the standard error of the mean is substantially affected — the true values of the standard error might be several times larger than the numbers given in the table. Unfortunately a correct computation of standard error requires estimates of covariances which are not currently available.

The numbers of probe reports received from each link for each interval in the 10-interval schedule are given in Tables 7 to 16. The discussion on correlation between travel times given above applies equally to the values for the standard error given in these tables.

The numbers of probe reports given in these tables do not correspond exactly with the numbers in Tables 1 and 2 in Section 1. The numbers in Tables 1 and 2 relate to the entire eleven-week data collection period for all TRF evaluations, while the numbers in Tables 5 to 16 relate only to data collected during the period from June 6 to August 4, from lpm to 7pm, which is used for SP updating.

In tables 5 to 16:

Number = number of probe reports in the sample
Mean = mean link travel time for the sample
S.D = standard deviation of the sample travel time
S.E. = standard error of the sample travel time

Table 5: Number of Probe Reports, 2-Interval Schedule: 1:00-4:00pm

Link	Number	Mean	S.D.	S.E.
1	2032	75.629	22.542	0.500
2	2085	43.829	28.693	0.628
31	940	62.838	31.268	1.020
32	1185	30.271	16.212	0.471
4	1189	95.423	33.064	0.959
5	1163	36.536	4.060	0.119
6	1164	45.304	9.747	0.286
7	1171	107.403	51.980	1.519
8	1025	55.633	21.228	0.663
9	1125	64.017	30.505	0.909
10	2023	60.255	30.408	0.676
11	1833	56.585	28.423	0.644
12	1822	74.869	22.522	0.528

Table 6: Number of Probe Reports, 2-Interval Schedule: 4:00-6:00pm

Link	Number	Mean	S.D.	S.E.
1	1793	70.843	24.172	0.571
2	1771	58.754	33.055	0.785
31	1307	66.516	32.168	0.890
32	551	41.548	19.624	0.836
4	558	119.057	47.059	1.992
5	555	37.978	7.528	0.320
6	548	56.801	26.643	1.138
7	500	225.366	120.821	5.403
8	580	104.586	73.363	3.046
9	613	198.796	106.922	4.319
10	1949	82.177	23.593	0.534
11	1830	52.713	27.810	0.650
12	1801	85.878	33.677	0.794

Table 7: Number of Probe Reports, l0-Interval Schedule: l:00-2:30pm

Link	Number	Mean	S.D.	S.E.
1	1194	75.742	21.183	0.613
2	1230	42.946	27.305	0.779
31	538	58.874	32.079	1.383
32	705	30.672	16.696	0.629
4	699	91.956	30.977	1.172
5	699	36.546	3.747	0.142
6	698	45.274	10.317	0.391
7	705	98.410	39.973	1.505
8	612	54.317	22.767	0.920
9	625	58.392	17.501	0.700
10	1080	53.985	28.976	0.882
11	974	57.727	27.714	0.888
12	974	74.340	19.634	0.629

Table 8: Number of Probe Reports, l0-Interval Schedule: 2:30-3:l0pm

Link	Number	Mean	S.D.	S.E.
1	521	74.240	22.207	0.973
2	510	43.373	27.747	1.229
31	243	65.626	30.422	1.952
32	284	28.930	14.196	0.842
4	288	99.972	35.553	2.095
5	293	36.369	3.439	0.201
6	274	45.526	8.246	0.498
7	274	109.365	58.128	3.512
8	251	55.426	16.752	1.057
9	343	62.656	24.580	1.327
10	623	61.136	29.191	1.169
11	570	52.300	26.736	1.120
12	551	74.564	24.650	1.050

Table 9: Number of Probe Reports, l0-Interval Schedule: 3:10-4:00pm

Link	Number	Mean	S.D.	S.E.
1	317	77.489	27.452	1.542
2	345	47.655	34.162	1.839
31	159	71.994	27.307	2.166
32	196	30.770	17.132	1.224
4	202	100.936	34.960	2.460
5	171	36.778	5.884	0.450
6	192	45.099	9.629	0.695
7	192	137.625	67.896	4.900
8	162	60.926	20.699	1.626
9	157	89.382	58.110	4.638
10	320	79.697	29.083	1.626
11	289	61.190	32.710	1.924
12	297	77.172	26.797	1.555

Table 10: Number of Probe Reports, l0-Interval Schedule: 4:00-4:40pm

Link	Number	Mean	S.D.	S.E.
1	530	73.251	26.939	1.170
2	536	57.799	29.282	1.265
31	374	68.198	31.447	1.626
32	184	41.473	19.338	1.426
4	190	122.384	47.855	3.472
5	186	37.747	5.385	0.395
6	191	48.801	14.666	1.061
7	188	166.851	89.004	6.491
8	203	90.892	47.099	3.306
9	228	162.079	93.124	6.167
10	596	78.044	25.166	1.031
11	571	52.217	27.064	1.133
12	573	80.679	25.539	1.067

Table 11: Number of Probe Reports, l0-Interval Schedule: 4:40-5:l0pm

Link	Number	Mean	S.D.	S.E.
1	494	71.004	23.443	1.055
2	475	59.956	42.538	1.952
31	354	65.602	31.270	1.662
32	141	40.979	18.385	1.548
4	148	112.108	43.502	3.576
5	153	37.078	4.375	0.354
6	146	49.795	14.511	1.201
7	133	187.323	75.881	6.580
8	143	98.811	70.535	5.898
9	148	187.128	117.610	9.667
10	518	83.718	23.793	1.045
11	487	51.450	27.854	1.262
12	482	88.618	48.856	2.225

Table 12: Number of Probe Reports, l0-Interval Schedule: 5:10-5:30pm

Link	Number	Mean	S.D.	S.E.
1	294	69.415	21.942	1.280
2	300	59.430	29.795	1.720
31	231	64.675	32.110	2.113
32	87	43.115	18.178	1.949
4	85	119.988	46.381	5.031
5	86	39.779	11.720	1.264
6	78	68.808	26.477	2.998
7	75	309.693	94.005	10.855
8	87	137.230	110.817	11.881
9	88	266.977	101.417	10.811
10	327	85.352	21.700	1.200
11	298	55.557	27.337	1.584
12	289	92.052	27.298	1.606

Table 13: Number of Probe Reports, l0-Interval Schedule: 5:30-5:40pm

Link	Number	Mean	S.D.	S.E.
1	154	67.045	21.473	1.730
2	147	61.585	27.927	2.303
31	121	72.934	34.112	3.101
32	42	38.214	19.226	2.967
4	40	137.450	53.619	8.478
5	39	40.436	15.988	2.560
6	47	86.915	50.666	7.390
7	25	350.880	166.345	33.269
8	45	105.533	55.413	8.261
9	39	243.308	78.055	12.499
10	150	85.140	24.848	2.029
11	142	51.979	25.701	2.157
12	142	92.324	28.060	2.355

Table 14: Number of Probe Reports, l0-Interval Schedule: 5:40-6:00pm

Link	Number	Mean	SD.	S.E.
1	321	69.751	23.337	1.303
2	313	56.588	27.404	1.549
31	227	63.626	33.365	2.214
32	97	42.557	23.196	2.355
4	95	114.653	46.692	4.791
5	91	37.209	3.388	0.355
6	86	59.116	28.922	3.119
7	79	308.886	134.469	15.129
8	102	111.676	78.960	7.818
9	110	220.273	95.963	9.150
10	358	82.684	20.716	1.095
11	332	53.178	30.174	1.656
12	315	82.575	22.228	1.252

Table 15: Number of Probe Reports, l0-Interval Schedule: 6:00-6:45pm

Link	Number	Mean	S.D.	S.E.
1	479	69.541	22.436	1.025
2	471	51.892	28.493	1.313
31	295	61.725	29.450	1.715
32	198	35.303	14.624	1.039
4	216	100.148	34.021	2.315
5	225	37.747	9.064	0.604
6	222	48.563	20.518	1.377
7	222	139.180	103.603	6.953
8	150	78.673	37.292	3.045
9	234	107.970	78.674	5.143
10	510	68.873	28.973	1.283
11	480	45.756	27.617	1.261
12	475	75.046	19.175	0.880

Table 16: Number of Probe Reports, l0-Interval Schedule: 6:45-7:00pm

Link	Number	Mean	S.D.	S.E.
1	277	65.025	20.810	1.250
2	266	52.444	24.249	1.487
31	136	52.897	23.086	1.980
32	147	34.789	14.014	1.156
4	137	89.584	22.193	1.896
5	139	35.921	3.235	0.274
6	139	43.122	8.523	0.723
7	155	85.503	39.511	3.174
8	143	69.559	17.065	1.427
9	162	71.358	42.594	3.346
10	299	59.211	35.133	2.032
11	268	43.056	23.777	1.452
12	289	72.232	17.561	1.033

3.3 Data Analysis

Besides updating link travel times, SP is also designed to construct and update a number of other quantities. Included among these are congested distance (the distance traversed by the probe vehicle at a speed of less than ten meters per second), congested time (the time during which the vehicle is stationary or traveling at a speed of less than two meters per second) and some detector-based quantities. These other estimates were only for internal TRF use and had no direct role in route guidance. It is our understanding that in recent revisions of the TRF design, these elements are no longer needed. Hence they were not included in the evaluation plans and were not evaluated as a part of this task. However, the updating procedures for these other quantities are identical to the link travel time updating procedure.

3.3.1 Data Sources

Link travel times are computed in two different ways: based on probes alone and based on both probe reports and detector reports. In the latter case, travel times are obtained from the Data Fusion component of TRF. Since very few links in the ADVANCE area have detectors, link travel times based on probes only are overwhelmingly the more important. Nevertheless, both types of travel times are updated by the SPU procedure. In the present evaluation we have examined both, although we have paid considerably more attention to the probes only case.

3.3.2 SPU Runs

The NFM estimates were originally constructed for June 5, 1995, using data created by the Network Flow Model. Their accuracy is improved by subsequent runs using probe data from specific time periods. After the BD for June 5, five SPU runs were made. Run 1, using the BD from June 5, utilized data from June 6-June 18. Run 2, using the SP from Run 1, was run through the algorithm incorporating data from June 16-July 9 . Run 3 used the SP from Run 2, as well as data from July l0-August 4. Both the original run, as well as runs 1 through 3, divided the lpm-6pm test frame into 2 time intervals, peak and non-peak. The remainder of the day, 6pm-1pm, was considered as one interval.

A second series of runs, paralleling the first, was also made. Rather than using the original interval schedule, this series of runs utilized an alternate interval schedule of 10 time intervals (Table 3 for the lpm-7pm frame). The remainder of the day, 7pm-lpm, remained in the original one-interval schedule. As with Run 2, Run 4 used the SP from Run 1 as its base, modifying it with data from June 19-July 9. Run 5, using the SP from Run 4, as well as the data from July l0-August 4, followed the same procedure. The time periods and interval schedules for each SP update are shown in the flow chart, Figure 4. This process provided us with two final sets of Static Profile estimates.
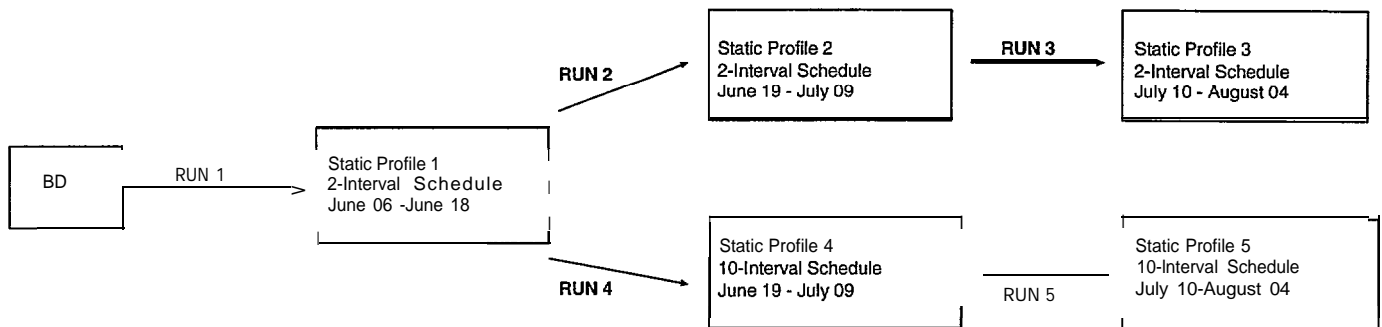
Figure 4: SP Updates: Time Periods and Interval Schedules

4 Base Data - Results

In the analysis of base data we compare various estimates with means and other measures of location or central tendency. We should note here that models of the NFM class tell us what link volumes and link travel times would be if everyone were to choose their shortest travel time routes.

Table 17 shows a comparison of off-peak BD travel time estimates with corresponding means, medians, upper and lower quartiles computed from actual probe data for each of the 12 links. Table 18 is the corresponding table for the peak period. We draw the readers' attention to the fact that for every link and time period, there is one BD estimate. This estimate is computed according to the method described earlier and no claim has ever been made that the estimate is of mean travel time. Precisely for this reason, it is important that we examine how the BD estimate compares with the entire distribution. Consequently, we have presented the four summary measures. These are given in Tables 17 and 18. For comparison of BD estimates with actual probe travel times see the histograms in Figures 9, 12 and 15.

It may be seen that for Links 5, 6 and 8 in the off-peak period and Links 5, 6 and 11 in the peak period, the correspondence of the BD estimate to the probe mean is fairly close. It might be noted that link travel times for Links 5 and 6 are very close to their cruise times, which are the times that would be taken to traverse the links at a constant speed of 35 mph (Link 5) and 25 mph (Link 6). Link 5 is a little traveled link terminating in an uncontrolled right turn, while Link 6 is a little traveled link terminating in a right turn at a stop sign. All other links end at traffic signal controlled intersections.

Overall BD estimates are somewhat disappointing. In order to understand why this might have occurred, we compared link volumes provided by the NFM with volumes obtained from detectors (Tables 19 and 20). While models of the NFM family have been used in the past primarily for estimating volumes, their accuracy in this situation appears limited. There does not seem to be a great deal of correspondence between the travel time estimate provided by the NFM and the actual volumes recorded by the detectors for either off-peak or peak situations. The closest relationship exists for Link 7, off-peak,

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Table 17: Base Data Travel Time Estimates (in seconds), 2-Interval Schedule: Off-Peak

	Base Data	Cruise	MNA 1pm -4 pm						
Link	lpm-4pm	Time	mean	stdev	max	Q_3	med	Q_1	min
1	56	45.9	75.6	22.6	278	89	72	56	35
2	36	29.3	43.8	30.1	255	39	31	28	20
31	—	—	62.8	31.5	212	86	60	39	23
32	76	22.6	30.1	16.1	161	29	25	23	18
4	64	54.9	95.4	33.1	213	112	87	70	45
5	33	32.7	36.5	4.1	74	39	37	34	25
6	44	43.3	45.3	9.7	159	49	43	39	27
7	47	33.4	107.4	52	412	131	106	62	33
8	55	42.3	55.6	17.6	172	62	51	43	27
9	105	48.1	64.0	30.5	370	64	56	52	42
10	32	25.8	60.3	32.7	319	91	58	29	20
11	35	25.7	56.6	28.9	179	83	62	29	22
12	61	45.9	74.9	23.6	236	88	71	58	36

Table 18: Base Data Travel Time Estimates (in seconds), 2-Interval Schedule: Peak

	Base Data	Cruise	MNA 4pm-6pm						
Link	4pm-6pm	Time	mean	stdev	max	Q_3	med	Q_1	min
1	54	45.9	70.8	23.4	159	83	62	50	39
2	34	29.3	58.8	33.8	573	84	66	29	22
31			66.5	33.3	299	87	50	39	22
32	79	22.6	41.5	19.5	153	53	33	26	20
4	65	54.9	119.1	47.1	308	148	03.5	80	53
5	33	32.7	38.0	7.5	140	39	37	35	27
6	53	43.3	56.8	26.6	251	62	47	41	20
7	56	33.4	225.4	120.8	732	317	191	132.5	35
8	44	42.3	104.6	73.5	723	108	80	66	37
9	175	48.1	198.8	107.6	850	265	198	101	47
10	34	25.8	82.2	25.4	230	91	81	66	27
11	57	25.7	52.7	31.1	206	99	58	46	26
12	46	45.9	85.9	35.7	974	101	84	60	41

where the NFM underestimated the detector volume by 16.4 vehicles. Other than that report, volumes vary widely between the NFM estimate and the recorded detector value, the greatest difference being 1287.6 vehicles (Link 1, off-peak).

Table 19: Detector Volumes and NFM Estimates: Off-Peak

Link ID		Detector Volume	NFM Estimate
8cb40		795.2	522
8cae7	11	886.2	1681
8cae8		493.6	198
8cabf		1036.0	1447
8cb24		529.0	498
88c9a8	7	666.4	650
891036		890.3	561
88d079		412.9	558
88cb2b	1	590.4	1878
88cad2		1158.4	1455
88cb20		1117.8	1623

Note: Both the Detector Volume and the NFM Estimate are average hourly flows. The detectors are all part of a closed loop system on Dundee Road in the study area. Three links (1, 7 and 11) are on the study route. The other detectorized links are cross-links which intersect with Dundee Road.

Assuming the detector volumes accurately reflect actual traffic flows, the tables showing detector volumes and NFM estimated traffic flows suggest the following:

1. peak flows on Dundee Road are generally overestimated by the Network Flow Model while flows on the cross streets are generally underestimated, although there is no consistent pattern for the off-peak period; this may account for the disappointing performance of the NFM procedure which computes green splits endogenously,

2. volumes on the cross streets are generally modeled more accurately than those on art erials, and

3. NFM volume estimates vary widely enough that travel time estimates are compromised.

Again, the NFM estimates are not as accurate as they might be. While the principle upon which the NFM model is based (every one chooses his/her minimum time route) may be challenged, it is unlikely that such models, when accurate inputs are provided, would not yield estimates that approximate true traffic volumes. Thus we surmise that either the cost functions used were inappropriate or the OD volumes, which were constructed

Table 20: Detector Volumes and NFM Estimates: Peak

Link ID		Detector Volume	NFM Estimate
8cb40		1124.4	999
8cae7	11	1172.2	2134
8cae8		720.4	373
8cabf		1376.5	1196
8cb24		799.4	372
88c9a8	7	979.1	958
891036		679.6	246
88d079		1246.0	487
88cb2b	1	566.5	1792
88cad2		1411.1	558
88cb20		1221.7	1811

Note: Both the Detector Volume and the NFM Estimate are average hourly flows.
The detectors are all part of a closed loop system on Dundee Road in the study area.
Three links (1, 7 and 11) are on the study route. The other detectorized links are
cross-links which intersect with Dundee Road.

partially on the basis of 1990 data, were obsolete. The latter observation is especially
relevant in a fast growing region such as the ADVANCE test area. We shall see later that
the mean travel times for some of the links are not constant over time. Thus conditions
change and we cannot expect BD estimates which remain constant to remain accurate
over the long term.

5 Static Profile Update - Results

Data analyzed in this section were collected as described earlier in this document. Using
a targeted deployment in a limited study area, probe vehicles collected data in separate
time periods, data which were then utilized in sequential Static Profile Update runs to
create estimates of travel times for specific links.

5.1 Updates 1, 2 and 3: 2-Interval Schedule

Table 21 shows the means of probe travel times for the l-4 pm period for all days for
which data were gathered for TRF evaluation. Also shown are the 3 updates (made for
June 18, July 09 and August 04) and, for the readers' convenience, the BD estimates.

For SP estimates the mean is the appropriate measure of travel time, at least for
evaluation purposes, because the aim of the SPU was to yield estimates of the mean
'under normal conditions', which we took to mean incident-free conditions. Therefore,

Table 21: Static Profile Travel Time Estimates (in seconds), 2-Interval Schedule: Off-Peak

Link	BD	SPU 1		SPU 2		SPU 3	
		est	probe	est	probe	est	probe
1	56	64.42	70.7	69.59	72.5	74.4	79.8
2	36	47.53	52.7	45.22	44	42.27	40.8
31		56.88	67.9	60.4	63.9	59.96	61
32	76	27.10	29.6	30.06	31.6	29.66	29.2
4	64	84.76	95.6	92.8	96.6	93.42	94.3
5	33	34.84	36.1	36.02	36.5	36.31	36.8
6	44	44.23	44.4	44.94	45.4	45.15	45.5
7	47	91.17	97	98.04	103.2	102.6	114.8
8	55	55.89	54.4	55.53	55.4	55.69	56.2
9	105	58.16	61.2	63.71	68.1	62.1	61.2
10	32	57.09	57.6	61.06	65.3	59.27	57.7
11	35	51.37	59.7	55.15	57.7	55.03	54.7
12	61	67.29	71.9	72.03	80.4	71.86	71.7

Note: For Tables 21 and 22, "est" refers to the SPU estimate of mean travel time and "probe" refers to the average travel time for that link as determined from actual probe data gathered in that time period (see Table 4).

the means used for comparisons do not include values from link reports where incidents were noted. It is also appropriate that SP estimates were designed to approximate the mean because estimates of travel times are used to estimate route travel times and the mean of route travel times is the sum of mean travel times of the links comprising the route. This property is not shared by all measures of location (e.g., the median or the mode).

It is apparent that the estimates are quite accurate in that they are quite close to the means of probe reported travel times, a point which is particularly true for the third update. Even when the BD estimates are relatively inaccurate, the corresponding SP estimate moves rapidly towards a more realistic value (in terms of actual data). This is particularly evident if we compare the overall means of probe travel times in Table 17 with the SPU 3 travel-time estimates in Table 21. It may be seen that there is a fair amount of variation from updating interval to updating interval for the same link. Therefore, it would be unreasonable to anticipate smaller differences between the means from one SP to the next. For example, consider Link 7 where the third SP estimate of 102.6 seconds has the largest difference (12.2 seconds) of all estimates from the corresponding mean probe report. While the first update shows good recovery from a rather inaccurate BD estimate, updating interval probe travel time means of 97, 103.2 and 114.8 seconds provide too much of a moving target. However, a discrepancy of 12.2 seconds for an average travel

time of over 100 seconds is hardly disastrous.

Table 22: Static Profile Travel Time Estimates (in seconds), 2-Interval Schedule: Peak

Link	BD	SPU 1		SPU 2		SPU 3	
		est	probe	est	probe	est	probe
1	54	64.1	71.1	66.92	68.9	69.09	72.3
2	34	57.28	62.3	58.47	59.5	58.06	56.6
31	—	61.71	65.3	63.85	65.7	65.27	67.8
32	79	35.13	40	39.75	40.7	41.22	42.2
4	65	94.63	104	112.82	117.9	116.5	120.5
5	33	36.11	37.2	36.79	37.5	37.7	38.2
6	53	52.73	52.4	54.56	54.5	56.23	58.3
7	56	204.38	244.8	200.2	200	219.35	238.8
8	44	113.4	134	76.56	75.6	82.11	118.3
9	175	231.71	255.3	177.83	155.3	196.44	218.7
10	34	82	91.8	80.45	79.8	80.36	80.4
11	57	65.36	60.7	49.17	44.5	51.4	56.7
12	46	75.27	83.7	81.48	94.2	80.45	79.3

Table 22 shows a comparison of mean link travel times and SP estimates for the peak period. Again, the overall performance of the SP procedure seems good. One of the third SP updates, Link 8, is relatively inaccurate. The circumstances leading to this discrepancy are unusual. The means of probe reports for the three update intervals are 134, 75.6 and 118.3 seconds. Not only is the mean for the second interval much smaller than the others, its variance is also small, giving the impression to the update algorithm that it is more reliable than the other estimates. Note also that while it does not have as dramatic an effect on SP estimates, a similar phenomenon exists for Links 7, 9 and 11, to a lesser extent for Link 10, and in a reverse direction for Link 12 (although Link 12 is a right-turning link). Note also that Links 8 through 12 are consecutive links. A possible explanation for this fluctuation is that some experimentation occurred with traffic signal timings.

Clearly, the dramatic fluctuation in probe travel times Link 8 experienced affected the estimate. Because of two reports which had travel times close to 1000 seconds, the average travel time was affected. However, because no incidents were noted for these reports, they were not deleted from our data set. In order to guard against such situations, the SP algorithm as designed had incorporated a test which would warn of such events and take some evasive actions. However, the test was not implemented. It is not clear whether the test would have been able to handle such a dramatic shift in mean travel time in one direction and then the other. Perhaps that part of the algorithm needs to be revised in light of the experience gained from Link 8. We could however argue that in this case

the probe means were the less good estimates of travel time; the SP estimates were more robust and therefore better. Ideally, we would also get information when changes are made to traffic signal timings.

5.1.1   Comparison of Travel Times with BD and Final SPUs

The data examined in the tables above can also be displayed and examined as histograms. The advantage of histograms is that they afford a comparison with the entire distribution. In histograms Figures 5-8, the upper arrow (or the only arrow, if only one **is** visible) shows the location of SPU3 and the lower arrow is the corresponding BD estimate. On some occasions the BD estimate falls outside the figure's range and is therefore not shown. The actual estimates are printed above each histogram.

Figures 5 and 6 portray the variations in travel times during the off-peak period for the twelve links of the long route. Each day of data collection has one average travel time for the 4:00 - 6:00 peak period and the 1:00 - 4:00 pm off-peak period. This is represented by a single observation on the histograms. The distribution for Link 1 in the off-peak period is typical. While the BD is only 56 seconds and therefore off the histogram, SPU3 represents the midpoint of the range of average travel times. The SPU3 estimate of travel time is 74.4 seconds and the mode (most frequently occurring value) in the distribution occurs at the 76-77 second level.

At the intersection of Dundee Road and Northgate Parkway, the two approaching links on our study route (Links 32 and 9) have BD levels higher than SPU3 and the differences are large. In the case of Link 32 the BD is more than twice the SPU3 and for Link 9 it is almost 70% higher. Perhaps some aspect of the intersection, such as the green time input to the NFM, did not accurately reflect actual conditions. Still, in both cases the SPU3 estimate portrays the most common driving circumstance reasonably well. Even the outlier in Link 9 does not greatly influence the magnitude of SPU3.

During the peak period (Figures 7 and 8) the pattern is similar but not identical. The BD is generally below the range of the daily averages (during the peak period) and again Link 32 is an exception. During the peak period Link 32 has a difference between BD and SPU3 which is of the same magnitude as in the off-peak case.

Again the final 2-interval SPU (SPU3) portrays the actual travel times with reasonable accuracy. Also, as in the off-peak period, Links 5 and 6, which almost never experienced congestion in the middle of the link, exhibit a small difference between the BD and SPU3 values.

In ten of the twelve links the BD is less than SPU3. Given the growth of the region in which in the study area is located it is possible the data input to the NFM and used to compute the BD were out of date.
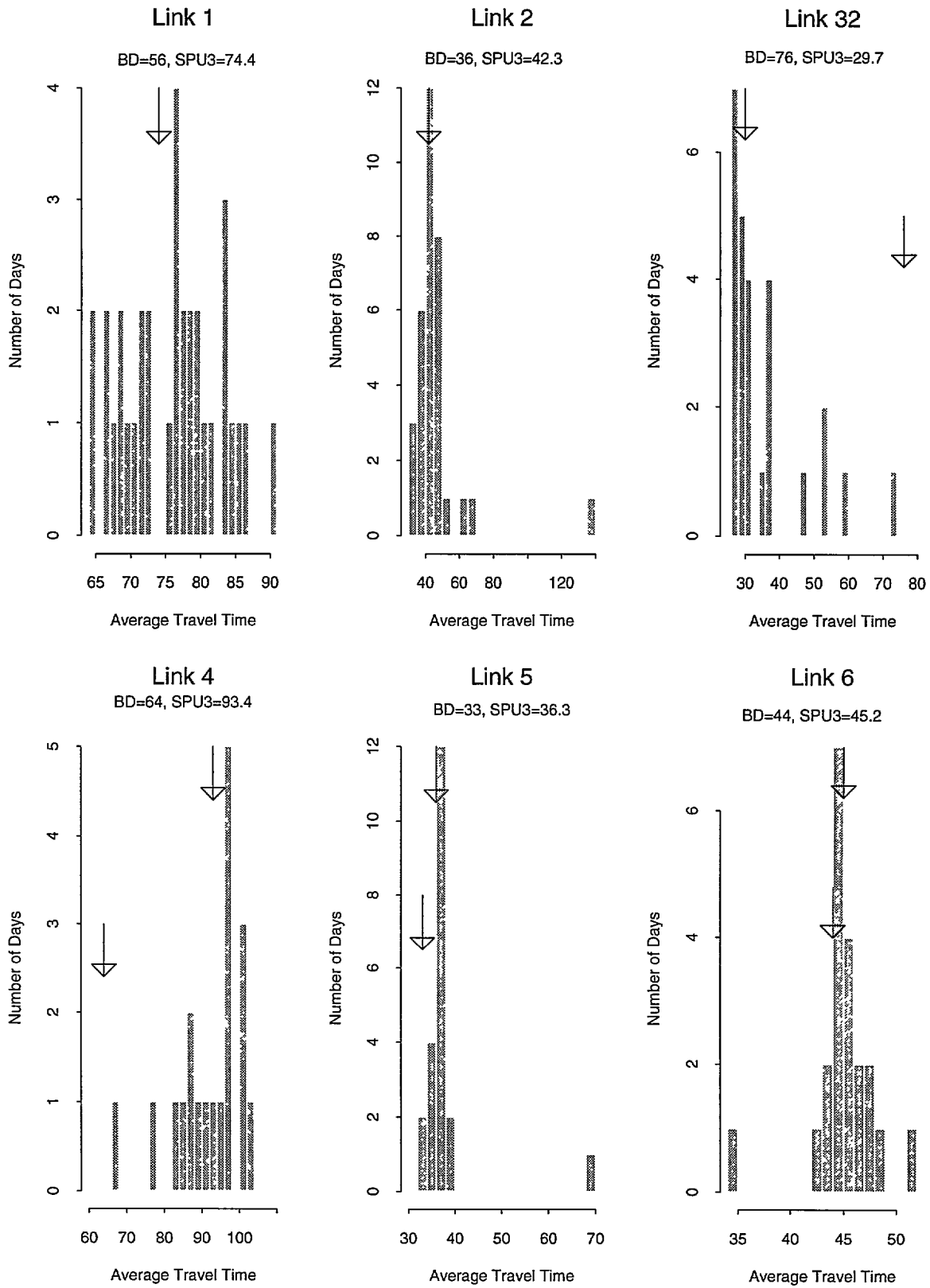
Figure 5: Average Travel Time (in seconds) by Number of Days, Links 1-6: Off-Peak
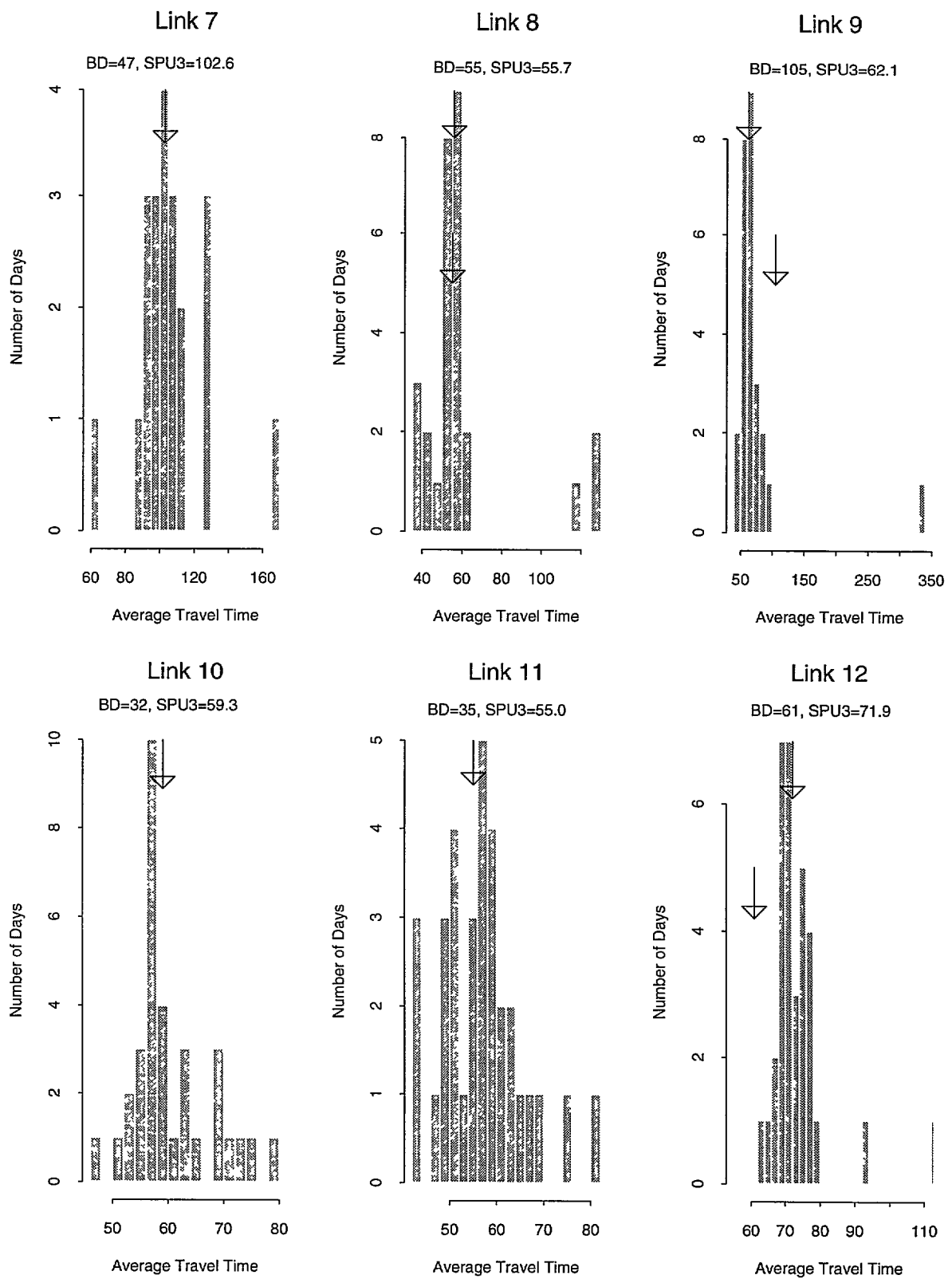
Figure 6: Average Travel Time (in seconds) by Number of Days, Links 7-12: Off-Peak

26
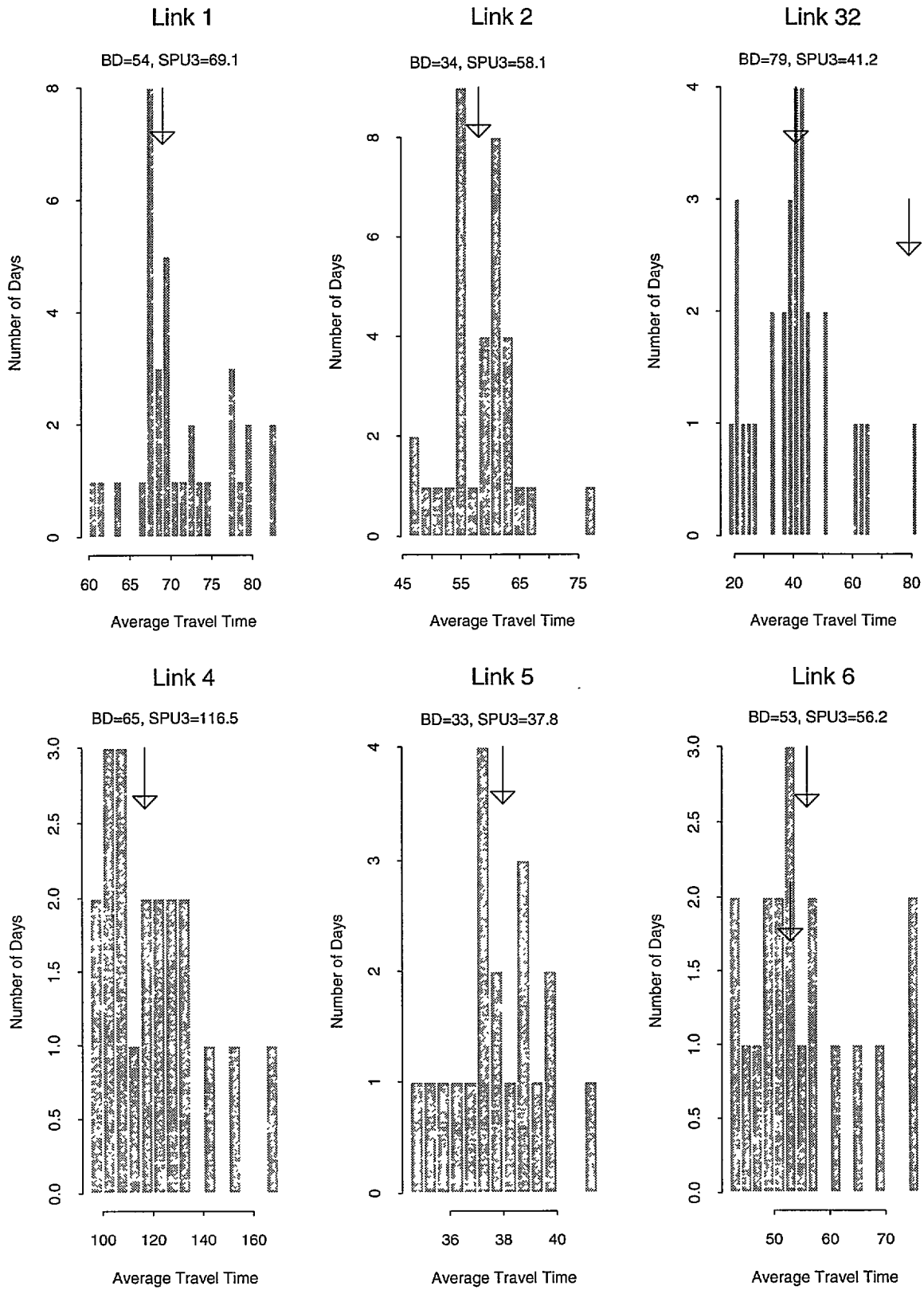
Figure 7: Average Travel Time (in seconds) by Number of Days, Links 1-6: Peak

27
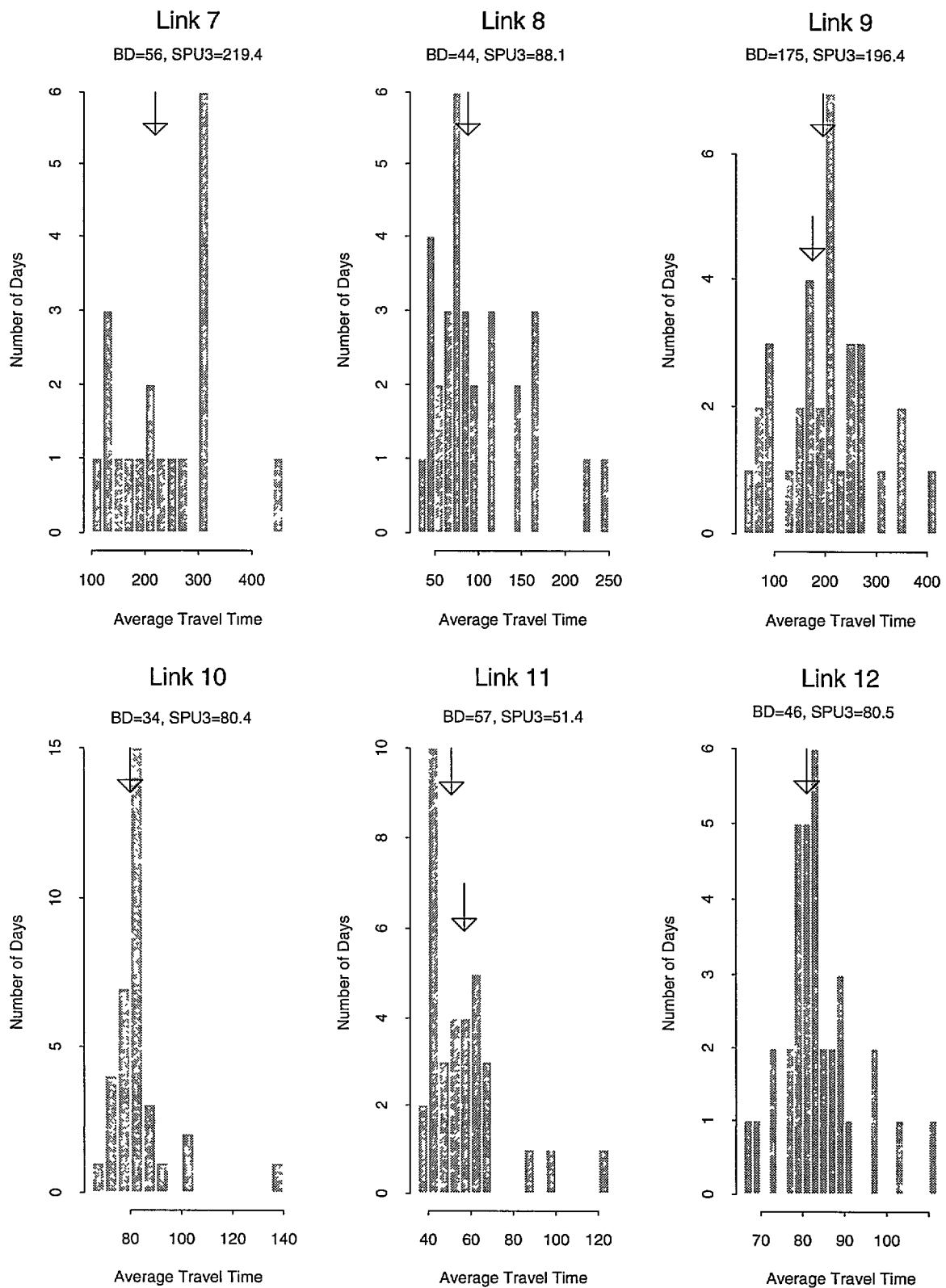
Figure 8: Average Travel Time (in seconds) by Number of Days, Links 7-12: Peak

5.1.2   Evaluation of SP and BD as Forecasts

Until now we have examined the quality of SP and BD estimates in terms of how well they described probe observations as a whole and, in particular for SP estimates, how close they came to the mean of probe observations. Both BD and SP estimates are used within the ADVANCE system as forecasts, albeit as default ones. Therefore, it is appropriate to also examine them in the context of this role. After all, the whole purpose of TRF algorithms is to make forecasts.

BD estimates are used as forecasts until the first SP estimates (SP1 in our case) are available. Then SP1 estimates are used until SP2 estimates are available. Then SP3 estimates would be used. It would be interesting to see how well BD estimates perform with respect to the actual link travel times during the time they are being used as forecasts. Similarly, it would be useful to examine how well SP1 estimates and SP2 estimates compare with link travel times during the time they would be used as forecasts. Obviously, we cannot examine SP3 estimates in the same way since no data were collected after they were constructed. Clearly, if the SP and BD estimates accurately reflect the actual condition on links during the time they are being used, there would be less need for dynamic broadcasts — a desirable situation. The best data available on link travel times are probe reported travel times. Since dynamic estimates are constructed over 5-minute intervals, we decided to compare SP and BD estimates with means of probe travel times over 5-minute intervals. Therefore, we subtracted the appropriate SP or BD estimate from such means and displayed the differences as histograms. That is, each histogram was constructed in the following way:

- means for 5-minute intervals contained in the appropriate update and SP interval were computed,

- the corresponding SP or BD estimate was subtracted from these means, and

- the numbers obtained in this way were displayed as histograms.

Clearly, values close to zero reflect cases where the probe means were very similar to the corresponding estimate. This process was repeated for every SP interval and update interval.

The resultant histograms (Figures 9 to 15) show that the SP estimates, particularly the SP2 estimates perform very well in this role. Since in the implementation of ADVANCE, dynamic estimates are broadcast only if they differ from current SP or BD estimate by 20 seconds, it is easily seen that in several of the links examined (e.g., Links 2, 5, and 6), dynamic broadcasts would not occur very often under non-incident conditions. For some links (e.g., Link 7) the 5-minute mean is spread out so widely that no 60-second interval could cover them. Even in these cases, the SP2 estimates are positioned so near the center of the empirical distribution of these means that the number of times dynamic broadcasts would occur is minimal. Unfortunately, as would be expected from our earlier discussion, BD estimates do not perform as well.

5.1.3 BD and SPU as Forecasts: Off-Peak Period

The first set of histograms (Figures 9 to 11) in this section shows the the frequency of BD, SPU1 and SPU2 values subtracted from the five-minute period average travel times. In an ideal situation the distribution would be centered close to zero. The fact that the values are mainly positive reflects the earlier discussion of low BD values.

Figure 10 shows how quickly the SP values reflect the summer 1995 driving conditions. This figure shows the average five-minute travel times during the off-peak during the period from June 19-July 9 minus the SPU1 based on the driving activities in the period June 5-June 16 and the initial BD. The distributions are rather varied but the zero level generally appears, as it should, near the center of the distribution.

The SP is again updated using the data of Figure 10 and this update is used to forecast for the following data collection period, July 10-August 4. Figure 11 shows the results and in summary there are no substantial changes. Some of the distributions have assumed different shapes, but the zero level remains near their centers. Link 12 shows the most improvement. The previous SPU resulted in only positive differences (Figure 10) whereas in the final version the zero level (no difference between probe travel time and SP estimate) is near the center of the distribution.

While the mean is the most appropriate single number to compare with SP estimates, comparing the estimates with histograms reveals some additional important points. Optimally, we would want static (default) estimates to be accurate to the point that under incident-free conditions, dynamic estimates would only be broadcast rarely. The fact that SP estimates are close to the mode of the histograms shows they perform well in this capacity.

In the ADVANCE project, as implemented, dynamic broadcasts are relayed if dynamic estimates differ from static estimates by more than 20 seconds. Therefore, the histograms show that if dynamic estimates were the actual travel times, for many links there would rarely be a need to broadcast them under incident-free conditions. The links which constitute exceptions to this observation have ranges of travel times too wide to fit within 60 seconds. Overall, the SP estimates seem to perform exceptionally well in this regard.

5.1.4 BD and SPU as Forecasts: Peak Period

During the peak period the general rate of improvement is similar to that discussed above for the off-peak period. The initial comparison (Figure 12) shows that the corresponding subtraction of actual travel times minus BD are mainly positive. Link 32 remains a problem and there are some negative values for both Link 6 and Link 11, where the BD appears to be a good predictor of travel times.

By applying the first SPU the improvements are again substantial (Figure 13). Only Link 5 appears to have an undesirable result. The majority of the values for this link are negative and they are not balanced at zero like they are for the other links. This problem is cleared by the next SPU (Figure 14) where the distribution seems centered on the zero

level despite the extremely high outlier (over 600) which is barely visible on the figure. Note that the mean was adversely affected by this outlier and hence, on the basis of the histogram, the SP estimate seems much more accurate. In general the links in this last update have travel distributions which reflect SPU2.

Since it is hard to visualize the change portrayed by three set of histograms over three pages we display two sample links on one page (Figure 15). These two links, Link 10 and Link 11, have different travel time frequency distributions and, by chance, different relationships with the BD/SP antecedents are evident. Link 10 has a symmetric distribution for all three time periods and, after the poor fit with BD (all differences are positive), the second two distributions appear to be well centered on the zero level.

The distribution of Link 11 starts out being positively skewed and remains so for the other two periods, although the skewness declines. In this case, however, the BD is a reasonable predictor of travel time. The first SPU seems to overestimate by only a small amount and the bulk of the distribution is less than zero. By the last SPU the distribution is more symmetric and, more importantly, it is more centered on the zero value than in the previous case. Link 11 is an exception in that most other links follow the pattern of Link 10 where the BD is not a good predictor of travel time and the first SPU is a vast improvement.

Figure 9: Difference between Average 5-minute Travel Time and BD Estimate (in seconds) by Number of 5-minute periods: Off-Peak
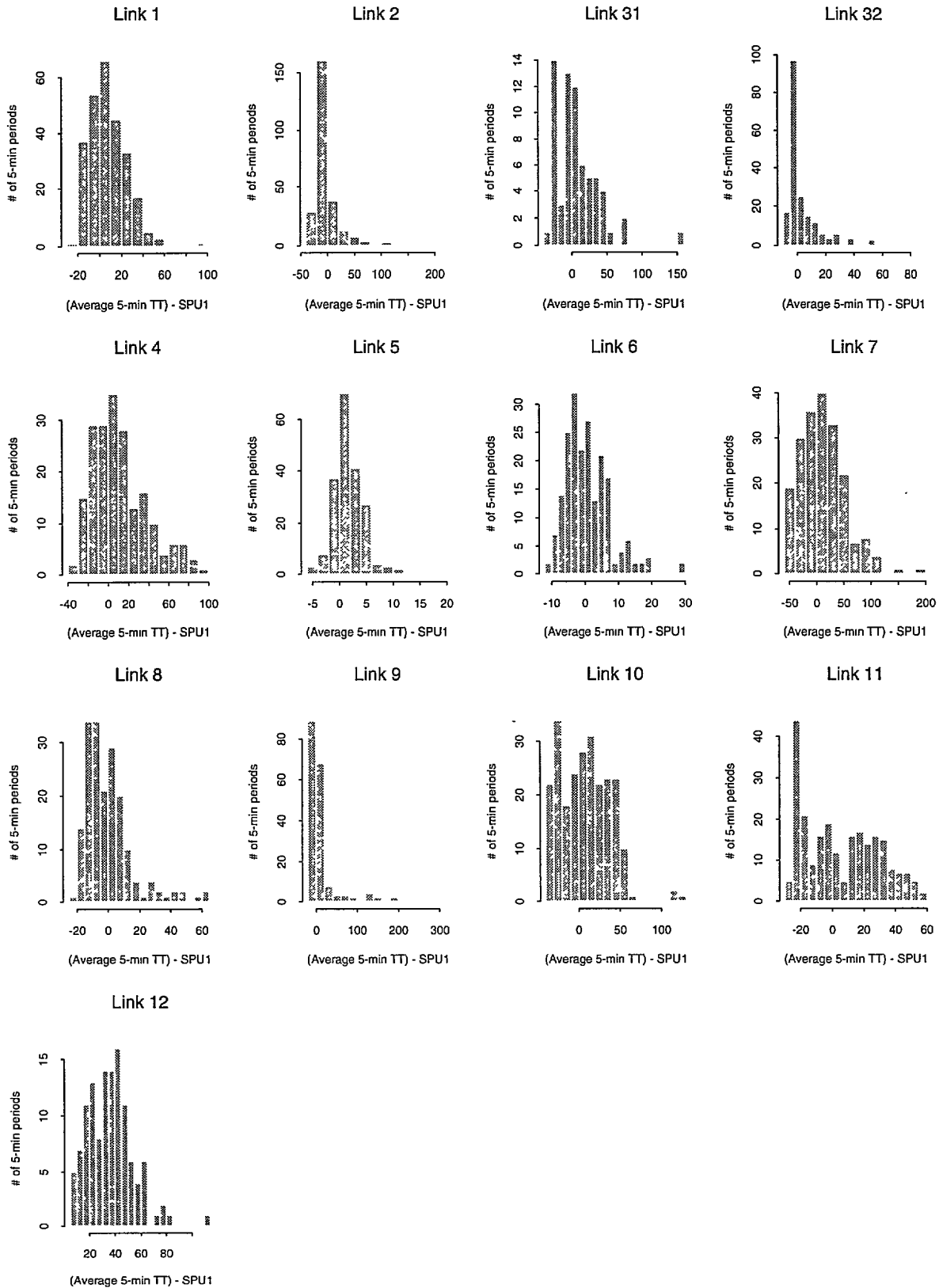
Figure 10: Difference between Average 5-minute Travel Time and SPU1 Estimate (in seconds) by Number of 5-minute periods: Off-Peak

33
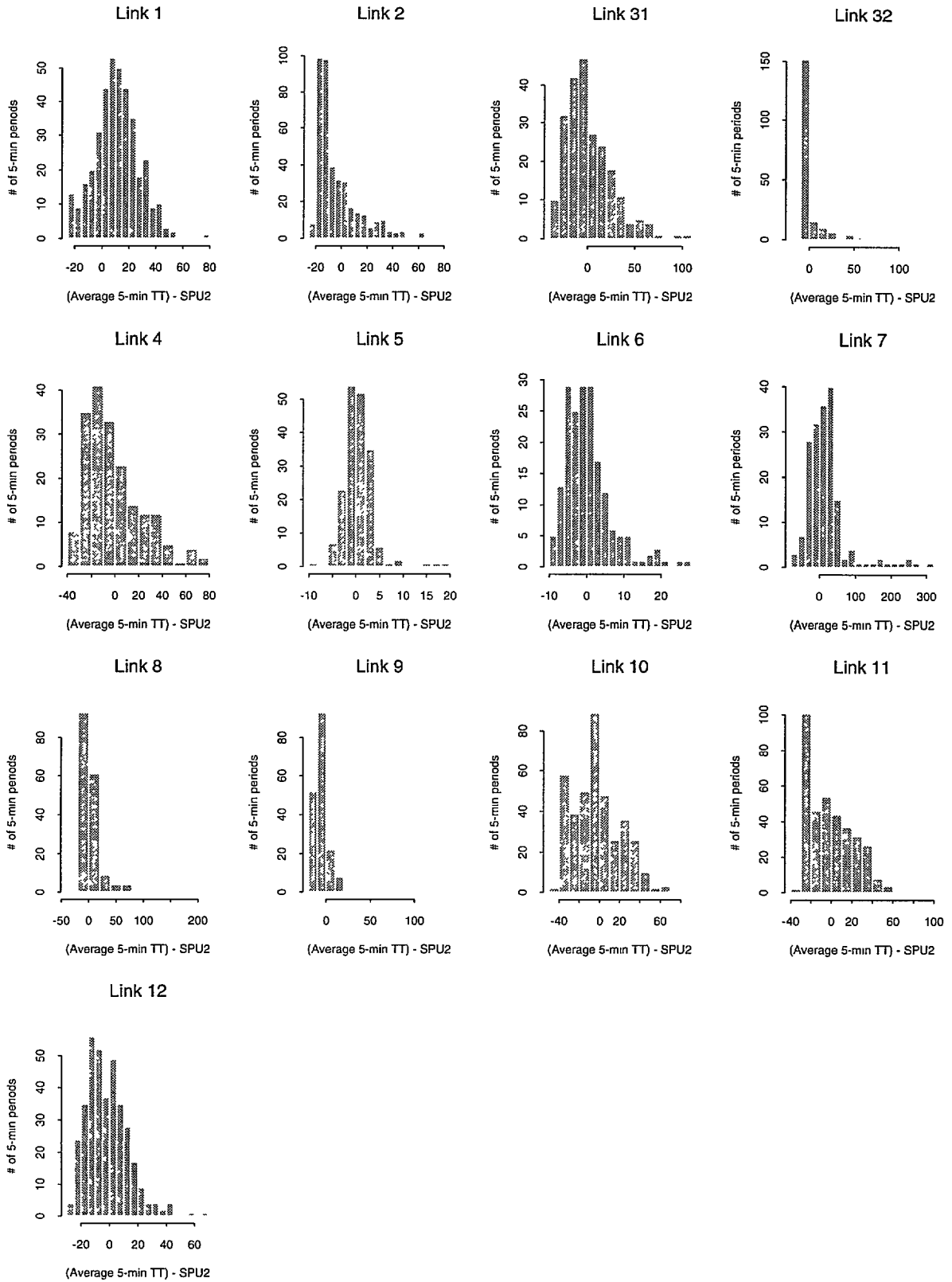
Figure 11: Difference between Average 5-minute Travel Time and SPU2 Estimate (in seconds) by Number of 5-minute periods: Off-Peak
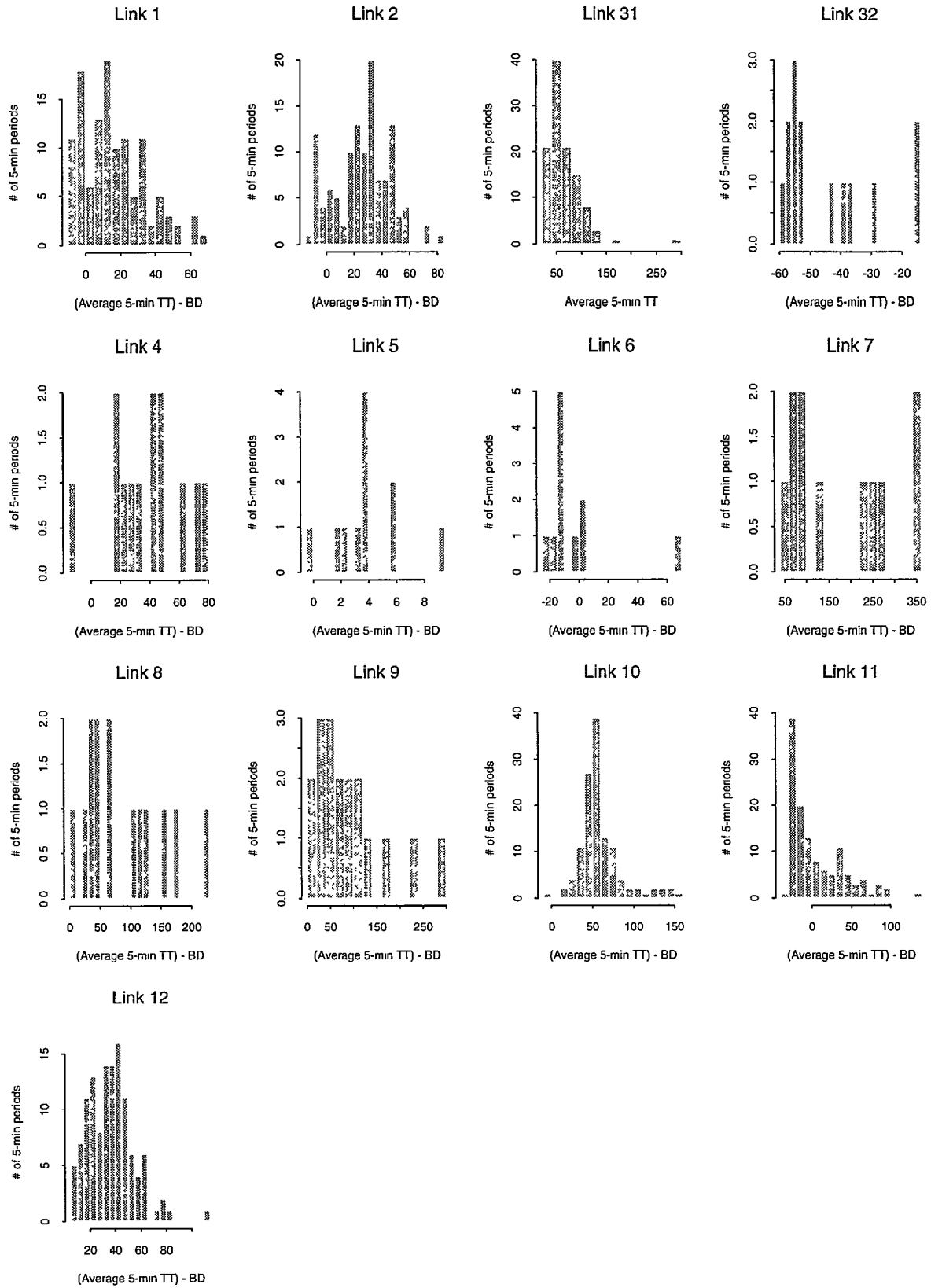
Figure 12: Difference between Average 5-minute Travel Time and BD Estimate (in seconds) by Number of 5-minute periods: Peak
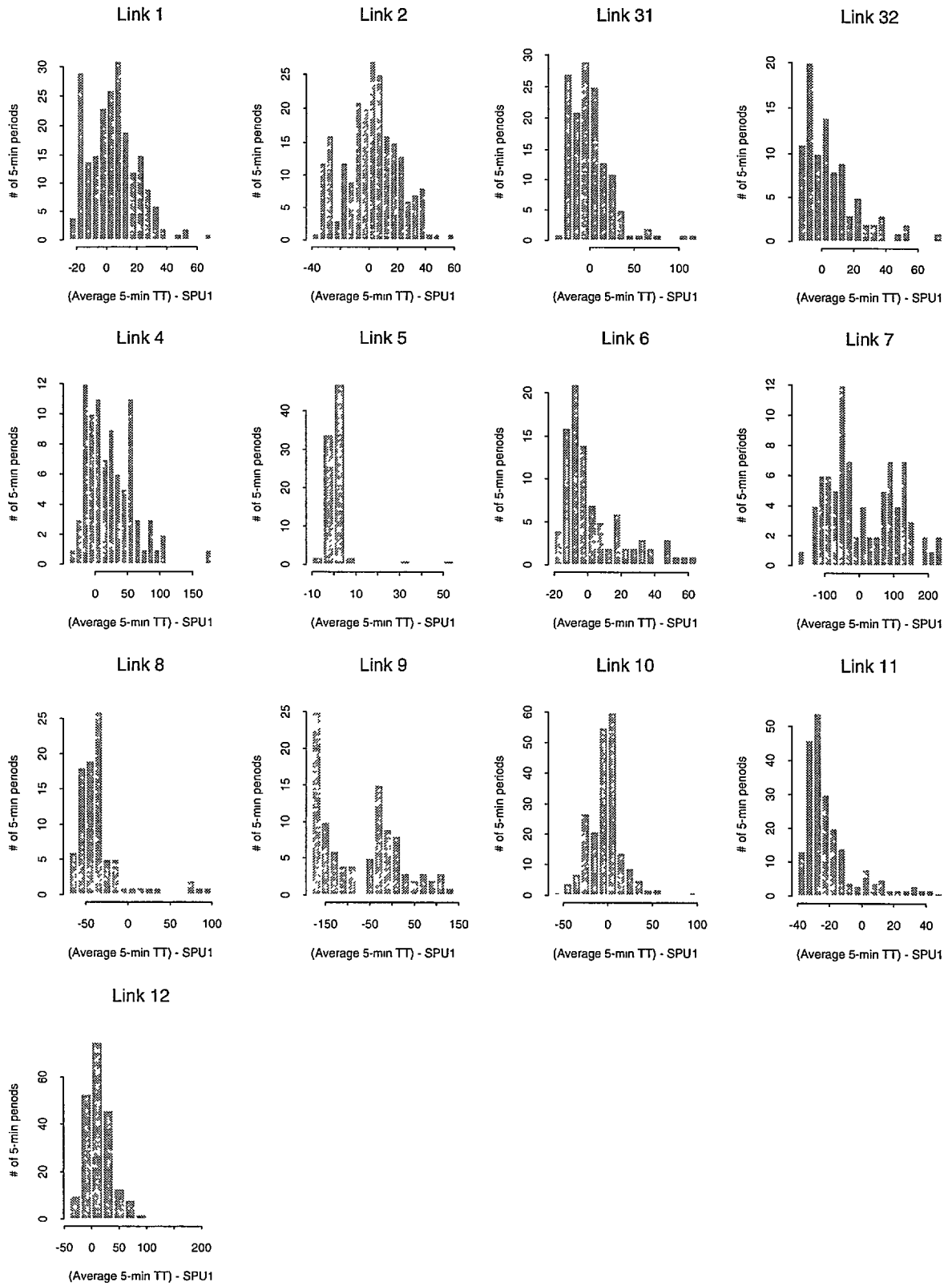
Figure 13: Difference between Average 5-minute Travel Time and SPU1 Estimate (in seconds) by Number of 5-minute periods: Peak

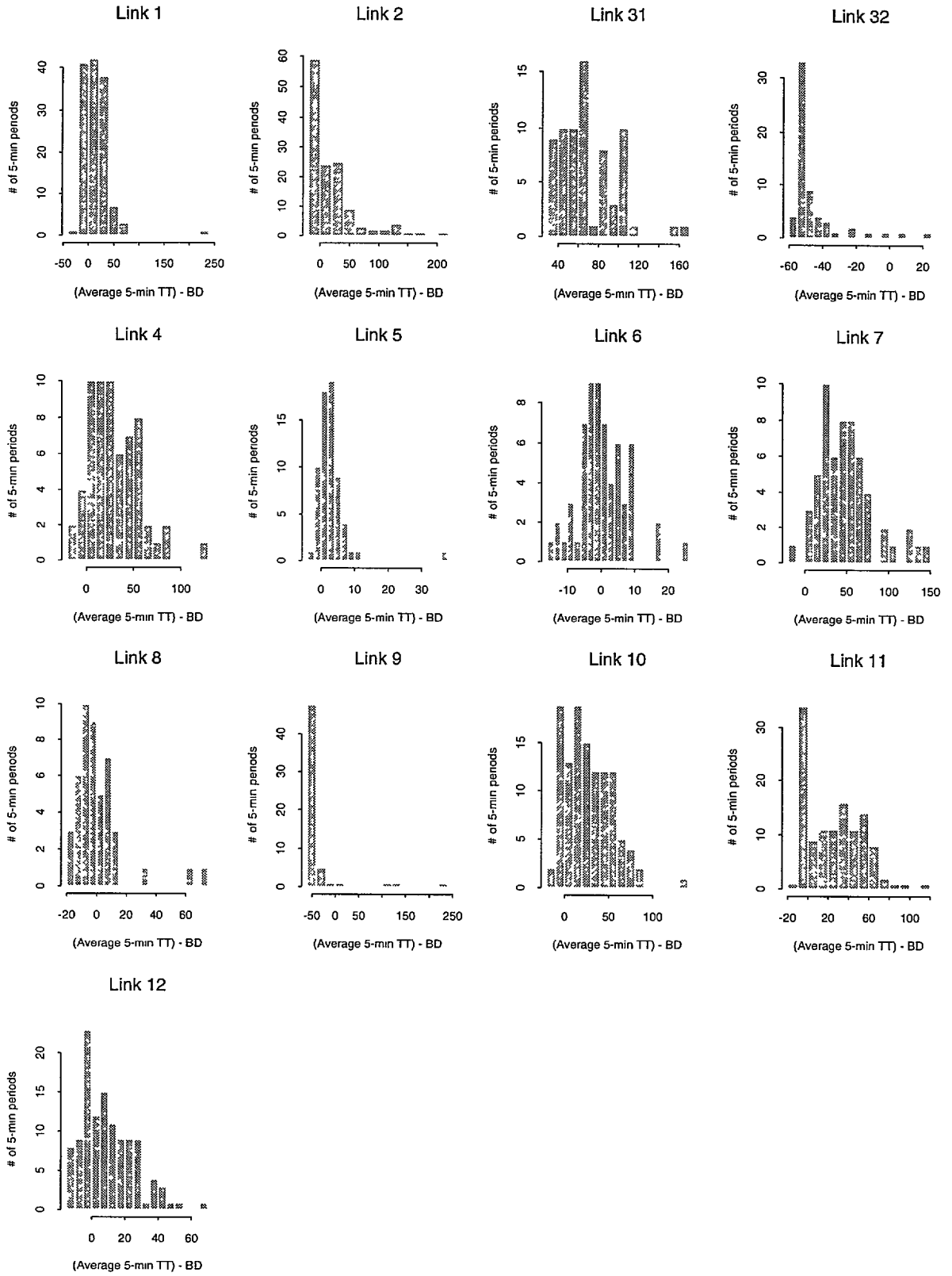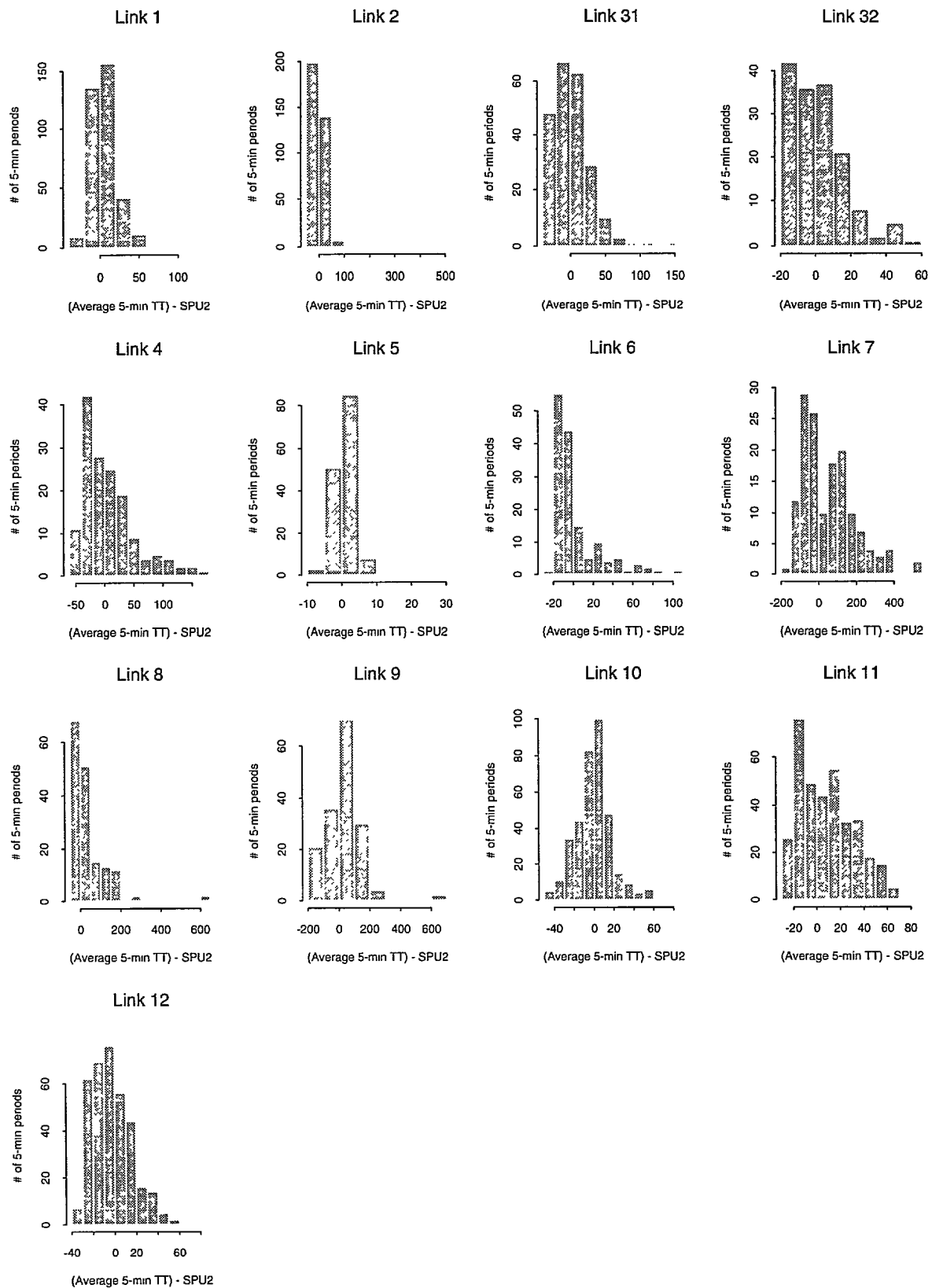Figure 14: Difference between Average 5-minute Travel Time and SPU2 Estimate (in seconds) by Number of 5-minute periods: Peak
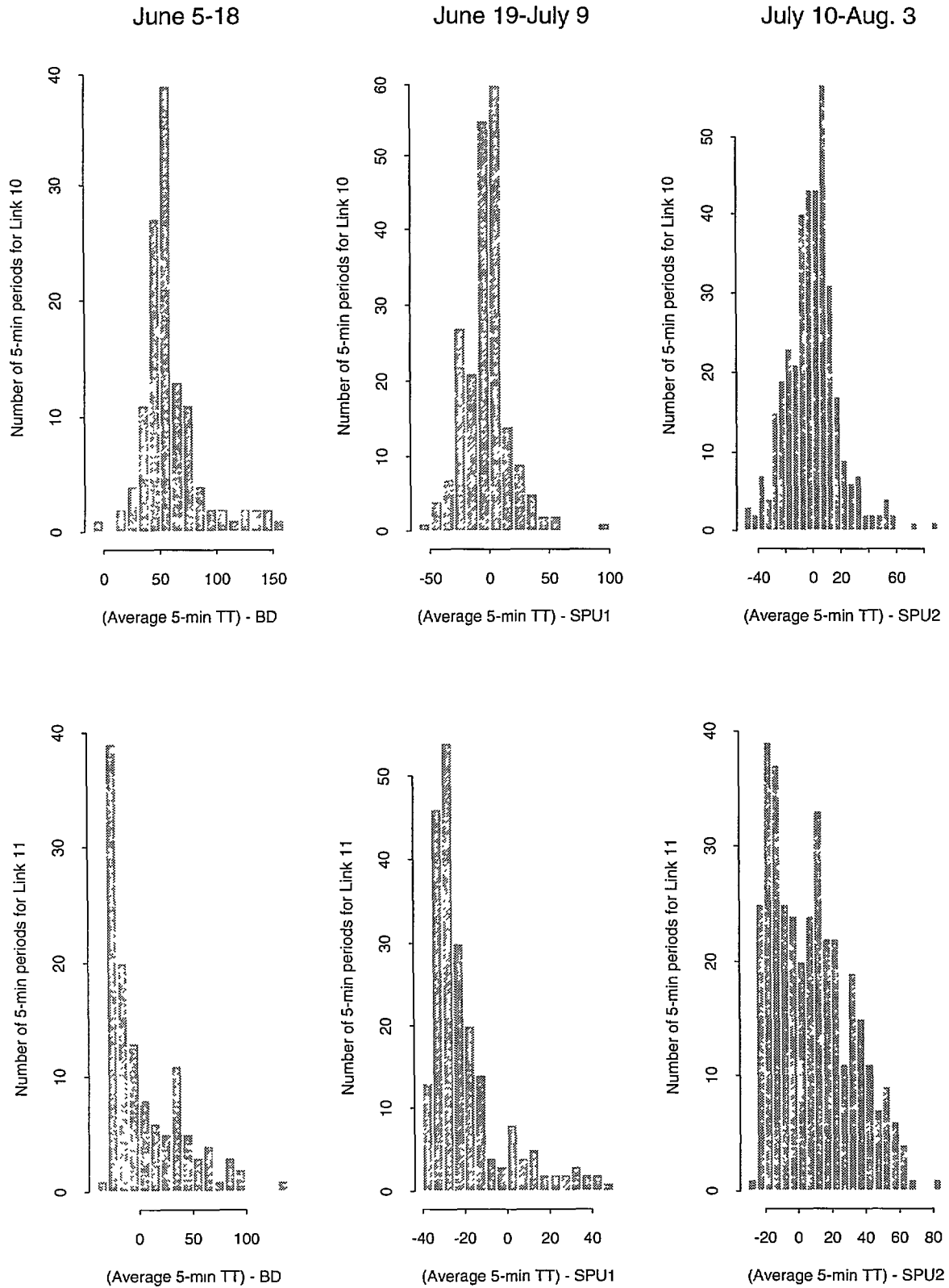
Figure 15: Difference between Average 5-minute Travel Time and BD, SPU1 and SPU2 Estimates (in seconds) by Number of 5-minute periods: Links 10 and 11

Table 23: SPU3 Travel Time Estimates (in seconds) Compared to Probe Travel Times: Off-Peak

Link	SPU3 estimate	Mean Probe Travel Time	S. E. Probe T.T.	Difference probe T.T. - SP3
1	74.40	75.63	0.50	1.23
2	42.27	43.83	0.63	1.56
31	59.96	62.84	1.02	2.88
32	29.66	30.27	0.47	0.61
4	93.42	95.42	0.96	2.00
5	36.31	36.54	0.12	0.23
6	45.15	45.30	0.29	0.15
7	102.60	107.40	1.52	4.8
8	55.69	55.63	0.66	-0.06
9	62.10	64.02	0.91	1.92
10	59.27	60.25	0.68	0.98
11	55.03	56.58	0.66	1.55
12	71.86	74.87	0.53	3.01

5.1.5 Hypothesis Test

Tables 23 and 24 present the SP3 estimates for each link in the peak and off-peak periods. Also shown are the average probe travel times for data collected throughout the study period (June 6-August 4), the standard error of these travel times, and the difference between SP3 estimates and probe travel times.

It is apparent from these tables that for most links during the off-peak period (Table 23), the difference between SP3 and probe means for the corresponding SP interval is 3 times the standard error (S.E.) or less. The only exceptions are Links 7 and 12. In the peak period (Table 24) exceptions are Links 1, 8 and 12. We know that the true value of the standard error of the mean is several times the calculated S.E. We also know that the SP3 estimates are random variables. Therefore, there is little reason to doubt the hypothesis that SP3 estimates and probe means have the same expected values; i.e., there is no cause to suspect that the SP3 estimates are biased.

The ETP stated there are two hypotheses to be tested. The first hypothesis is that the NFM consistently and accurately estimates travel times. The second hypothesis to be tested is that the SP consistently and accurately estimates travel times. A formal test of hypothesis, beyond what we have already stated would be difficult for a number of reasons. The SP3 estimates and the probe means being based partially on the same data are not independent, precluding the use of standard 2-sample tests. Moreover, the standard errors of probe means are underestimated by the SE's, as already stated. Nevertheless, we are convinced that any bias in SP estimates is effectively negligible.

Table 24: SPU3 Travel Time Estimates (in seconds) Compared to Probe Travel Times: Peak

Link	SPU3 estimate	Mean Probe Travel Time	S. E. Probe T.T.	Difference probe T.T. - SP3
1	69.09	70.84	0.57	1.75
2	58.06	58.75	0.79	0.69
31	65.27	66.52	0.90	0.25
32	41.22	41.55	0.84	0.33
4	116.50	119.06	1.99	2.56
5	37.70	37.98	0.32	0.28
6	56.23	56.80	1.14	0.57
7	219.35	225.37	5.40	6.02
8	82.11	104.59	3.05	22.48
9	196.44	198.80	4.32	2.36
10	80.36	82.12	0.53	1.76
11	51.40	52.71	0.65	1.31
12	80.45	85.88	0.79	5.43

5.2   Updates 4 and 5: l0-Interval Schedule

The SPUs for the lo-interval schedule are shown in Tables 25 through 34. As with the 2-interval updates, these estimates are quite accurate. Note that these updates occurred on the basis of less data per time period, and in some cases very little data. While most estimates can be seen to be on target, others (e.g., Link 7 for SPU4 and SPU5 for the 3:10-4:00 time interval, Table 27) are not as accurate, although rarely are they completely off the mark.

A close examination of the conditions show that the quality of SP estimates suffers when the following two conditions are present:

- the mean for the as designed lo-interval schedule is markedly different from the static estimates for the first SP estimate for the time period containing the appropriate SP interval (recall that the first SP update was conducted only for the 2 intervals: l-4 pm and 4-6pm), and

- the number of observations in the interval is relatively small.

These conditions give us a clue as to what causes the less accurate estimates. The larger intervals of the 2-interval schedule would generally have far larger numbers of observations than the smaller as designed intervals. Thus, the SPU algorithm 'thinks' that SPl is based on more observations and consequently must be far more reliable than

the mean from the smaller interval, which is based on fewer observations. As a result, the algorithm places greater weight to SPl values.

A solution to this problem would be to do the following: We should not mix static profile estimation for 2 intervals with those for larger numbers of intervals. That is, we should not start developing lo-interval estimates by first constructing 2-interval estimates. The l0-interval SPU's need to be constructed directly from the BD estimates in parallel with the 2-interval SPU's. This is illustrated in Figure 16 which shows an alternative schedule of SP Update time periods and intervals (compare with Figure 4). This shows that subsequent SP runs using the 10-interval schedule are always based on previous updates using the l0-interval schedule. Since the 10-interval estimates initially might not be too reliable owing to the paucity of data given the smaller interval size, we might prefer not to use them initially. As the 10-interval estimates improve over subsequent updates, we should then provide these to the MNA's and stop updating at the 2-interval level. We could, for example, use static profile 1A then move to the 10-interval schedule and profiles 2B and 3B.
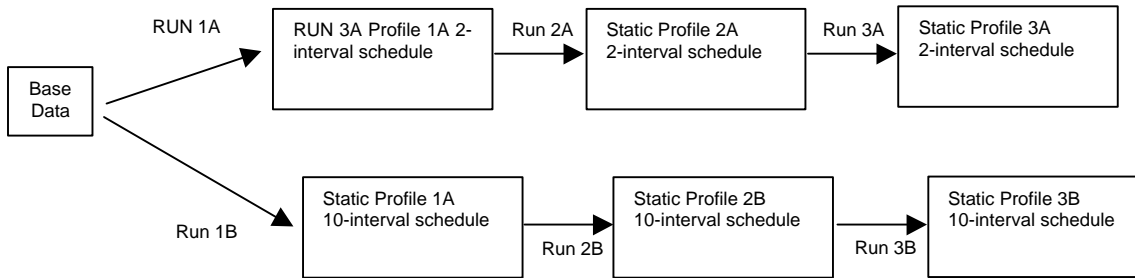
Figure 16: Alternative SP Update Time Periods and Interval Schedules

Table 25: Static Profile Travel Time Estimates (in seconds), lo-Interval Schedule: **1:00- 2:30** pm

	Probe	June 6 - July 23)		SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	**74.4**	21.2	**73**	68.89	**72.8**	**73.54**	79.3
2	**42.6**	**28.7**	**31**	46.11	**44.8**	**42.22**	**40.2**
31	**61.3**	**32.6**	**53**	**57.68**	**59.3**	**56.96**	**57.3**
32	**30.5**	**16.6**	**25**	**29.73**	**31.8**	**29.77**	**29.9**
4	**92**	**31**	**83**	**89.39**	**92.7**	**90.37**	**92.0**
5	**36.5**	**3.7**	**37**	**36.01**	**36.6**	**36.21**	**36.5**
6	**45.3**	**10.3**	**43**	**44.86**	**45.6**	**44.95**	**45.2**
7	**98.4**	**40**	**104**	**95.49**	**99.8**	**97.43**	**100.7**
8	**53.6**	**16.8**	**49**	**54.63**	**53.7**	**54.67**	**54.9**
9	**58.3**	**17.4**	**55**	**59.88**	**60.9**	**57.23**	**56.7**
10	**54.8**	**31**	**37**	**57.72**	**58.9**	**55.16**	**51.5**
11	**60**	**28**	**68**	**54.79**	**58.6**	**55.76**	**56.8**
12	**75.9**	**20.1**	**72**	**70.89**	**78.2**	**71.33**	**71.8**

Note: For Tables 25 to 32, the heading "Probe (June 6 - July 23)" refers to measures of location derived from data collected by probes over the period June 6-July 23, the heading "est" refers to the SPU estimate of mean travel time (in seconds), the heading "probe" refers to the average travel time (in seconds) for that link as determined from actual probe data gathered in that time period (see Table 4).

Table 26: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 2:30- 3:l0 pm

	Probe	June 6	July 23	SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	72.3	21.6	70	65.88	68.9	69.8	79.2
2	42.3	28.7	31	45.03	41.2	43.8	41.9
31	70.9	31.9	68	59.07	68.5	59.71	62.8
32	28.9	14.2	25	27.93	29.9	28.02	28.1
4	100	35.6	90	90.36	104.1	91.99	96.2
5	36.4	3.4	35	35.35	36.0	35.86	36.8
6	45.5	8.2	43	44.55	45.3	45.02	45.9
7	109.4	58.1	105	91.66	93.2	96.48	125.6
8	55.4	16.8	52	55.74	55.3	55.86	56.1
9	62.6	24.6	58	61.43	67.5	59.62	59.1
10	62	31.7	58	59.0	66.3	59.32	60.0
11	52.4	26.8	35	51.76	52.6	51.67	51.7
12	76.2	26.4	69	68.84	83.9	69.25	70.2

Table 27: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 3:10- 4:00 pm

	Probe	June 6	July 23	SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	76.5	28.1	74.5	66.55	75.8	69.44	84.2
2	47.8	35.8	33	47.01	45.0	44.75	41.6
31	70.4	26.8	68	60.78	71.9	63.43	73.4
32	30.8	17.1	25	28.3	34.0	28.38	28.8
4	100.9	35	92	88.89	98.6	91.01	98.0
5	36.8	5.9	35	35.16	36.2	35.3	38.4
6	45.1	9.6	43	44.39	45.1	44.57	46.0
7	137.6	67.9	125	96.04	125.3	98.55	175.4
8	61.1	20.7	58	57.38	60.8	57.76	62.9
9	89.9	58.3	66	60.35	97.9	62.33	86.2
10	83.1	30.8	89	61.18	84.6	64.26	77.2
11	60.5	33.7	43	52.23	62.9	53.36	53.9
12	77.8	27.8	71	68.3	83.1	69.01	75.6

Table 28: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 4:00-4:40 pm

	Probe	June 6 - July 23)		SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	70.6	23.7	62	65.18	68.1	67.45	75.9
2	58.9	27.9	60	57.97	60.0	57.54	56.0
31	65.6	30.8	52	63.27	68.1	64.95	70.2
32	41.2	19	31	37.34	38.5	39.88	42.4
4	122.4	47.9	109	107.3	118.2	114.7	126.1
5	37.7	5.4	37	36.61	37.6	37.46	37.9
6	48.8	14.7	44	48.45	47.9	49.12	49.5
7	166.9	89	139	145.9	140.9	162	181.5
8	91.2	47	77	71.53	70.4	75.55	100.6
9	162.1	93.1	173	140.6	101.5	155.4	191.6
10	77.7	27.3	79	78.73	73.2	78.28	77.4
11	49.5	27	39	52.54	42.7	53.72	58.3
12	83.1	26.3	79	79.24	89.8	76.81	72.6

Table 29: Static Profile Travel Time Estimates (in seconds), lo-Interval Schedule: 4:40-5:l0 pm

	Probe	(June 6 - July 23)		SPU4		SPU5	
Link	Mean	S.D.	Median'	est	probe	est	probe
1	70.5	23.5	64	65.77	69.8	67.38	71.6
2	61.9	45.2	66	57.97	60.1	58.02	58.8
31	63.9	30.5	49	62.68	65.1	63.5	69.6
32	40.9	18.4	35.5	36.83	37.5	39.56	43.1
4	112.1	43.5	93	105.5	114.8	107.6	110.8
5	37.1	4.4	37	36.34	36.5	36.82	37.4
6	49.8	14.5	45.5	51.55	50.7	51.14	49.5
7	187.3	75.9	179	167.1	163.4	183.4	201.7
8	99.9	70.9	80.5	75.57	74.1	77.34	112.3
9	187.5	118.1	187	187.5	124.9	194.7	216.3
10	83	25.3	81.5	81.54	81.2	81.21	80.8
11	48.5	27.7	37	53.26	42.1	53.91	57.4
12	90.8	52.8	85	76.59	99.4	78.16	81.1

Table 30: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 5:10-5:30 pm

	Probe	June 6 - July 23)		SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	68.9	23	62	64.99	68.2	65.71	70.0
2	61	29.7	70	57.29	57.3	57.34	57.9
31	65.4	34.4	52	61.94	62.9	61.46	59.7
32	43.4	18.1	44.5	39.82	44.9	41.03	42.3
4	120	46.4	112	401.3	129.8	108.2	115.2
5	39.8	11.7	37	36.54	40.4	37.8	39.4
6	68.8	26.5	63	59.52	65.2	64.65	70.5
7	309.7	94	315	265.1	281.5	289.5	321.2
8	138.2	111.1	88	75.91	72.2	79.43	167.2
9	266.7	102.8	248	238.6	247.1	245.7	279.0
10	85.5	23.5	85	82.82	84.3	82.78	82.7
11	54.3	27.8	43	60.97	49.7	60.48	58.0
12	93.4	27.5	89	79.02	100.6	80.47	86.5

Table 31: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 5:30-5:40 pm

	Probe	June 6 - July 23)		SPU4		SPU5	
Link	Mean	S.D.	Median	est	probe	est	probe
1	66.9	21.6	60	64.52	67.3	64.83	65.9
2	61.9	28.3	70.5	57.38	58.6	57.53	60.4
31	69.8	37	52	61.75	62.1	63.63	78.7
32	37.4	18.3	27.5	37.02	42.4	37.11	36.9
4	137.4	53.6	139	98.83	120.5	107.9	148.8
5	40.4	16	37	36.44	36.7	36.66	42.5
6	86.9	50.7	74	64.54	72.9	72.28	94.6
7	350.9	166.3	352	227.3	285.5	267.4	402.2
8	105.5	55.1	82	76.14	72.1	79.69	116.8
9	245.4	78	249.5	243.8	257.7	242.96	235.8
10	84.9	27.3	81	82.84	88.5	82.64	81.7
11	50.6	25.6	43	61.63	49.1	60.99	55.4
12	93.4	29.1	94	76.74	95.6	78.32	88.7

Table 32: Static Profile Travel Time Estimates (in seconds), 10-Interval Schedule: 5:40-6:00 pm

| | Probe | June 6 - July 23) | | SPU4 | | SPU5 | |
Link	Mean	S.D.	Median	est	probe	est	probe
1	68.6	24.1	61	65.13	70.2	66.59	71.2
2	58.3	27.6	64	57.77	60.4	56.96	51.6
31	64	37.6	51	62.41	67.9	61.93	61.4
32	43.2	23.3	38	38.23	44.0	40.4	42.3
4	114.7	46.7	93	102.5	110.9	106.2	118.5
5	37.2	3.4	37	36.54	36.8	36.92	37.5
6	59.1	28.9	45	53.51	55.7	55.64	62.6
7	308.9	134.5	323	261.6	281.1	279.4	323.7
8	113.4	79	78.5	100.1	93.4	105.5	121.7
9	223.1	97.8	206	231.76	231.8	225.6	215.4
10	81	22.1	82	81.55	80.8	81.79	82.9
11	52.4	31.7	39	57.7	44.1	56.66	52.4
12	83.9	22.8	83	77.84	86.2	78.29	80.0

Table 33: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 6:00-6:45 pm

| | Probe | June 6 - July 23) | | SPU4 | | SPU5 | |
Link	Mean	S.D.	Median	est	probe	est	probe
1	67.9	21.9	60	64.63	66.8	66.57	71.3
2	54	28.2	47	46.10	56.2	47.07	50.4
31	62.8	30.5	52	60.43	63.0	60.46	61.3
32	35.2	15.1	29	32.07	32.8	33.23	37.5
4	100.7	32.9	92	84.07	100.9	87.05	103.0
5	38.1	10	37	35.62	39.1	35.99	36.6
6	50	22.3	43	43.91	44.6	44.42	53.2
7	148.2	107.7	120	71.18	114.2	76.16	176.6
8	83.5	41.8	74.5	65.79	73.5	67.59	88.0
9	115.6	82.3	72.5	67.35	105.9	72.47	115.1
10	70.8	28.1	71.5	72.18	65.5	69.42	64.2
11	42.1	23.3	33	38.6	36.0	40.05	46.7
12	75.8	19.8	73	71.16	76.0	71.89	74.0

Table 34: Static Profile Travel Time Estimates (in seconds), l0-Interval Schedule: 6:45-7:00 pm

| | Probe (June 6 - July 23) | | | SPU4 | | SPU5 | |
Link	Mean	S.D.	Median	est	probe	est	probe
1	64.2	22.5	56	62.71	61.1	63.37	65.3
2	51.2	25	47	45.2	55.0	45.95	48.7
31	52.5	32.6	41	57.74	50.0	56.9	53.9
32	34.5	18.2	28	32.84	36.4	33.12	33.5
4	87.1	23.8	84	81.77	89.1	83.77	90.5
5	36.1	4	35	35.43	35.9	35.59	36.0
6	42.8	8.6	41	45.32	42.9	43.42	43.7
7	82.9	39.4	76	68.02	79.1	72.4	93.1
8	67.7	16.9	70	64.29	67.4	67.3	71.1
9	66.4	39	54	65.3	74.0	66.2	69.8
10	52.2	32.2	41	73.8	61.2	69.56	54.2
11	41.2	24.2	33	36.49	34.1	37.33	45.7
12	72.8	17.3	71	69.26	69.9	69.94	72.4

5.2.1 **Evaluation of SPU4 Estimates as Forecasts**

Since there are only two SPUs with the lo-interval data there can be only one check of its performance, namely the driving experience after SPU4. Figure 17 illustrates the differences between SPU4 and the average 5-minute travel times during respective intervals. To make the figure manageable we have selected three links (Links 2, 10 and 11) and four of the ten time intervals. Two of the intervals are during the off-peak and two are for the peak period.

With the zero level on the horizontal axis marking correspondence between SPU and average travel time, this level seems to well describe the central point of most distributions. Note that even for the ten-minute interval (5:30-5:40 pm) where we have fewer observations than for the other time intervals the zero level describes the data relatively well. Again the SPUs act as very good predictors of travel time.
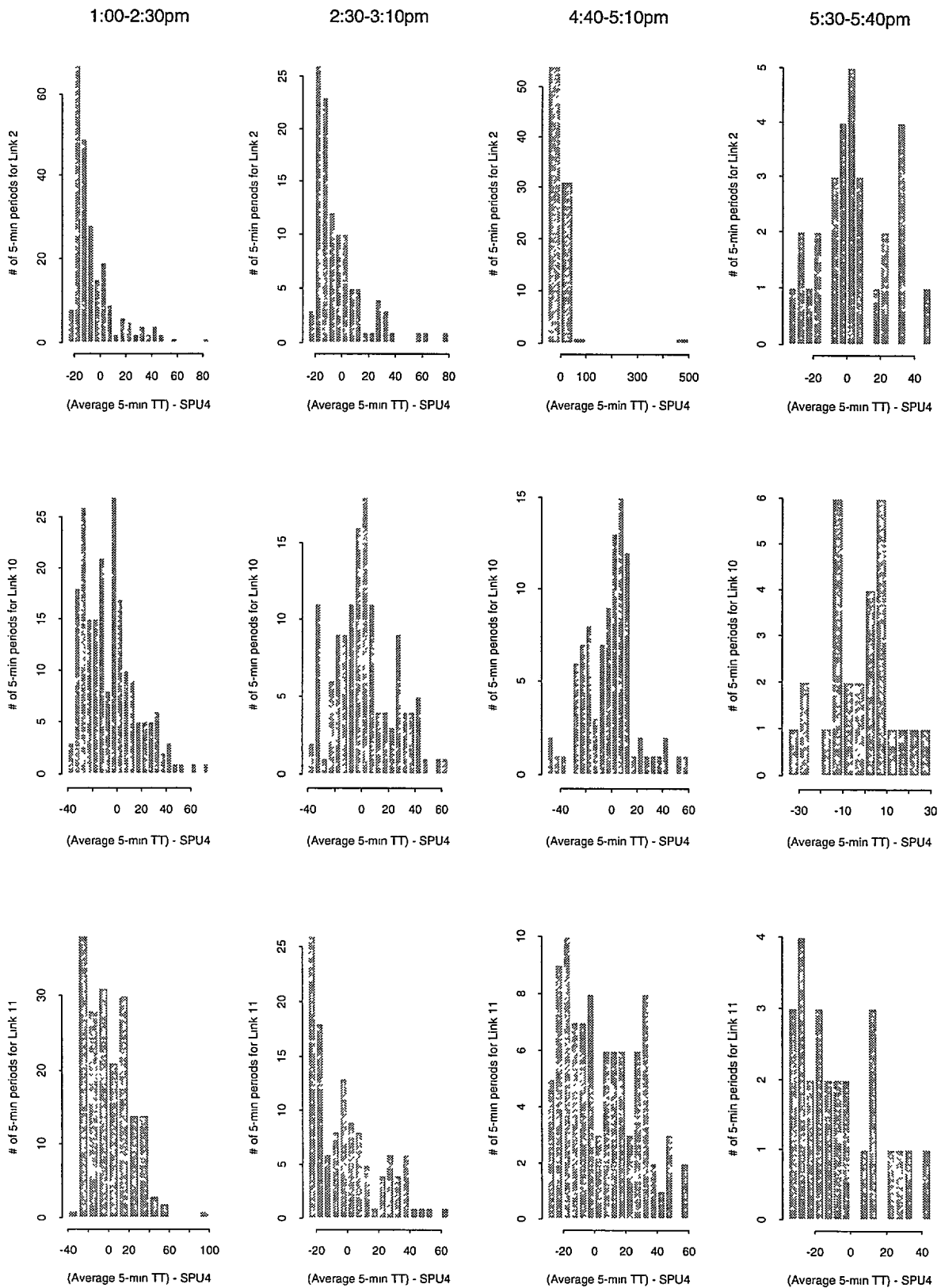
Figure 17: Average 5-minute Travel Time (in seconds) by Number of 5-minute periods, Links 2, 10 and 11: SPU4

6 SPU Results - Fused Data

The SPU runs were performed using fused data, that is, data received both from probe data and from inductive loop detectors in the road. For details of the data fusion process see ADVANCE Report No. 48.

6.1 2-Interval Schedule: Static Profile Updates 1, 2 and 3

The output from SPU runs using fused data are given in Tables 35, 36 and 37 for SPU runs 1, 2 and 3. Comparing these results with Tables 21 and 22, it may be observed that SP estimates of travel time based on fused data are quite accurate but are not as good as those estimates based on probe data alone. The additional data from detectors appears to adversely affect the estimates. This observation leads to the conjecture that data fusion may not be yielding accurate estimates, itself a subject which could be investigated in a later report.

For SPU 1 the initial estimate of travel time is the BD estimate; for SPU 2 the initial estimate is the output of SPU 1; for SPU 3 the initial estimate is the output of SPU 2 (see Figure 4).

Table 35: SPU 1 Travel Time Estimates (in seconds) for Links 1, 7 and 11 using Fused Data

Time	Link 1		Link 7		Link 11	
	Initial estimate	SPU1	Initial estimate	SPU1	Initial estimate	SPU1
13:00-16:00	56.00	66.72	84.90	91.28	39.41	48.72
16:00-18:00	54.00	64.96	55.94	103.40	70.36	63.76
18:00-24:00	52.96	63.47	43.94	75.73	31.70	43.01

Table 36: SPU 2 Travel Time Estimates (in seconds) for Links 1, 7 and 11 using Fused Data

Time	Link 1		Link 7		Link 11	
	Initial estimate	SPU2	Initial estimate	SPU2	Initial estimate	SPU2
13:00-16:00	66.72	72.29	91.28	96.91	48.72	51.48
16:00-18:00	64.96	67.68	103.40	134.52	63.76	48.30
18:00-24:00	63.47	63.77	75.73	76.04	43.01	38.54

Table 37: SPU 3 Travel Time Estimates (in seconds) for Links 1, 7 and 11 using Fused Data

Time	Link 1		Link 7		Link 11	
	Initial estimate	SPU3	Initial estimate	SPU3	Initial estimate	SPU3
13:00-16:00	72.29	76.99	96.91	100.57	51.48	51.05
16:00-18:00	67.68	69.83	134.52	148.69	48.30	49.88
18:00-24:00	63.77	65.69	76.04	76.25	38.54	40.11

6.2 10-Interval Schedule: Static Profile Updates 4 and 5

The output from SPU runs using fused data are given in Tables 38, and 39 for SPU runs 4 and 5. The conclusion that fused data appears to be giving us less accurate travel time estimates than those developed from probe data alone, also appears to hold true for these runs.

For SPU 4 the initial estimate is the output of SPU 1; for SPU 5 the initial estimate is the output of SPU 4 (see Figure 4).

Table 38: SPU 4 Travel Time Estimates (in seconds) for Links 1, 7 and 11 using Fused Data

Time	Link 1		Link 7		Link 11	
	Initial estimate	SPU4	Initial estimate	SPU4	Initial estimate	SPU4
13:00-14:30	66.72	71.51	91.28	94.26	48.72	51.17
14:30-15:10	66.72	68.87	91.28	92.00	48.72	49.09
15:10-16:00	66.72	69.67	91.28	96.14	48.72	50.38
16:00-16:40	64.96	66.33	103.40	117.38	63.76	50.84
16:40-17:10	64.96	66.48	103.40	121.98	63.76	52.14
17:10-17:30	64.96	65.95	103.40	117.96	63.76	58.85
17:30-17:40	64.96	65.36	103.40	107.72	63.76	60.05
17:40-18:00	64.96	65.94	103.40	116.92	63.76	55.69
18:00-18:45	63.47	64.90	75.73	75.88	43.01	39.60
18:45-19:00	63.47	63.18	75.73	75.78	43.01	37.55
19:00-24:00	63.47	62.67	75.73	75.86	43.01	39.78

Table 39: SPU 5 Travel Time Estimates (in seconds) for Links 1, 7 and 11 using Fused Data

Time	Link 1		Link 7		Link 11	
	Initial estimate	SPU5	Initial estimate	SPU5	Initial estimate	SPU5
13:00-14:30	71.51	76.34	94.26	96.08	51.17	51.48
14:30-15:l0	68.87	72.17	92.00	94.95	49.09	49.09
15:10-16:00	69.67	75.82	96.14	99.37	50.38	50.13
16:00-16:40	66.33	68.45	117.38	126.23	50.84	51.55
16:40-17:l0	66.48	68.17	121.98	132.71	52.14	52.37
17:10-17:30	65.95	67.66	117.96	131.00	58.85	57.90
17:30-17:40	65.36	66.07	107.72	112.08	60.05	58.89
17:40-18:00	65.94	67.65	116.92	127.13	55.69	54.47
18:00-18:45	64.90	67.02	75.88	75.96	39.60	41.01
18:45-19:00	63.18	64.05	75.78	75.86	37.55	38.32
19:00-24:00	62.67	63.81	75.86	76.02	39.78	40.57

7 Conclusions.

The SPU algorithm on the whole yields very good estimates. Even if initial BD estimates are inaccurate, SPU very quickly adjusts the values to acceptable levels.

However, we present the following suggestions for improvement if a procedure like SPU is implemented in the future:

- Arrangements should be made to get information on changes in traffic signal timings and other similar changes and the SPU algorithm should be capable of adjusting estimates accordingly.

- The SPU algorithm should be capable of detecting dramatic changes in travel times and be able to take appropriate action. While such a capability was designed, the design should be revisited in the light of some of the results from this evaluation.

- While not identified as a part of the current effort, there has been some concern over Static Profile Updates being step functions. Perhaps we should consider constructing continuous SP Updates. A piecewise linear SPU might not require additional space on the storage media. Instead of interval end-points and value, we would need to store interval end-points and slope. However, new procedures might have to be developed to construct estimates.

- If a large number of SPU intervals (such as our lo-interval schedule) is used, the updating process for it should start right at the beginning of the data collection,

although we might supply only estimates for a smaller number of intervals to the on-board real-time route guidance system.

- When adequate probe data are available, little is to be gained by supplementing them with detector data.

While these suggestions could improve the SPU procedures, we reiterate that even as implemented they work very well, particularly those using probe data only.

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Glossary

ANOVA - Analysis of Variance, a standard statistical procedure

Attribute Database - a database containing updatable information necessary for on-line data fusion, travel time prediction and incident detection. Attributes include link length, traffic control type.

Base Data (BD)/Base Data Estimates - travel time predictions for specific links at specific times as derived from the NFM.

Chicago Area Transportation Study (CATS) - The electronic network description file supplied by CATS. The file is used by the TRF group along with the MIF file from Motorola to build the ANR file.

Cruise Time - the time it would take a vehicle to traverse a link, in the absence of congestion, at a constant speed, usually the posted speed limit + 5 mph

Interval - **see SP Interval** and **Updating Interval.**

Mobile Navigation Assistant (MNA) - An in-vehicle navigation system designed and built by Motorola that determines vehicle position, performs route planning based on current traffic information, and provides dynamic route guidance information to the driver.

Network Flow Model (NFM) - the model developed by the TRF group based upon the contents of the *ADVANCE* Network Representation (ANR). The network flow model analyzes the ANR to produce link travel times and link flows by time period and day type.

Off-Peak - that portion of the day considered to have lighter traffic flow, defined in the experiment as lpm-4pm. The 2-interval schedule considers this period as one interval, the lo-interval schedule as three intervals.

Peak - that portion of the day considered to have heavier traffic flow, defined in the study as 4pm-6pm. The 2-interval schedule considers this period as one interval, the lo-interval schedule as five intervals.

Run - one operation of the SPU process, using the field data and the previous SP as processed by the SPU algorithm.

Schedule - division of the time period (lpm-7pm) under consideration by the SPU, consisting of either two or ten intervals.

Static Profile (SP) - static information of the roadway link including day type, link ID and average travel times for a specific time period.

SP Interval - variable-length time period, as determined by the interval schedule, for which average travel times are determined by the SPU. Intervals can range from as long

as several hours to as short as **10** minutes depending on the interval schedule.

Static Profile Updating (SPU) - the revision of previous Static Profile travel times for links, during specific time periods, using information gathered from probe reports and processed through the SP algorithm.

Traffic **Information Center (TIC)** - **C**onsisting of the hardware, software, a centralized facility and operations personnel. It communicates to and from probes and external systems.

Traffic Related Functions (TRF) - Subsystem consisting of data fusion, vehicle dynamics, incident detection and travel time prediction algorithms.

Updating Interval - the period of days or weeks of probe data collection for which SP updates are revised, also referred to as updating time periods.